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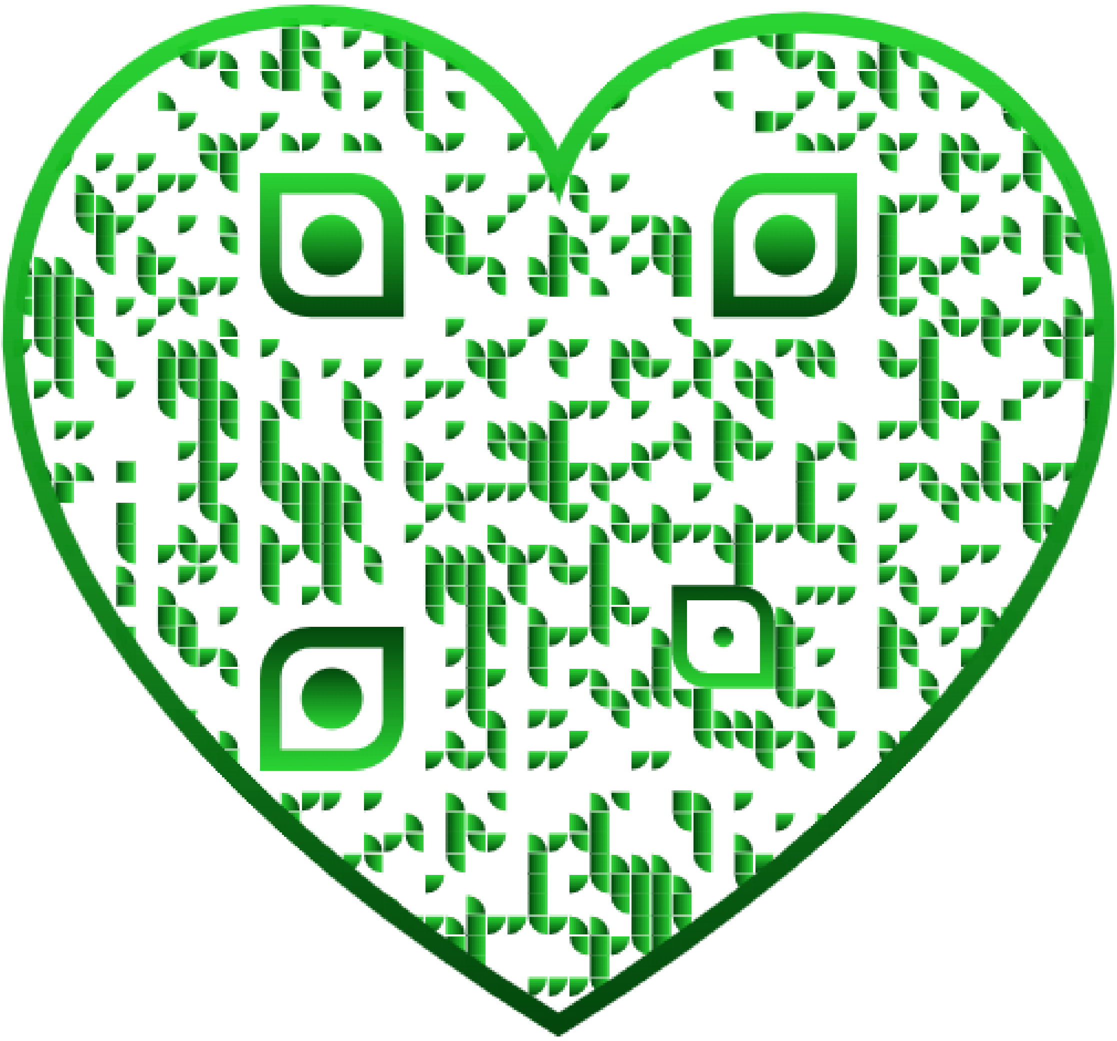
Vol. 54 • Issue 1



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ON THE COVER

Though it appears to be a photo, this image of the plane of the Milky Way is actually a projection of some 1.8 billion stars mapped by Gaia. COPYRIGHT: ESA/GAIA/DPAC; CC BY-SA 3.0 IGO. ACKNOWLEDGEMENT: A. MOITINHO

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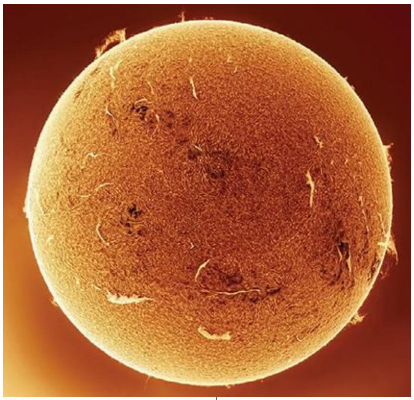
TOP: MARK JOHNSTON. ONLINE FAVORITES, LEFT TO RIGHT: *ASTRONOMY*: WILLIAM ZUBACK; AARSTUDIO/DREAMSTIME.COM; ALLEXXANDAR/DREAMSTIME.COM; SRIPFOTO/DREAMSTIME.COM

FROM THE EDITOR

Stars near and far



Advances in solar-imaging technology allow us to get up close and personal with our nearest star like never before. MARK JOHNSTON

In 2013, when I was leaving my astronomy graduate program and transitioning into journalism, I asked one of my professors which upcoming astronomy mission or telescope held the most promise to revolutionize the field.

There were many projects then in development: NASA's planet-hunting Transiting Exoplanet Survey Satellite (TESS); the powerful James Webb Space Telescope; and the revolutionary Large Synoptic Survey Telescope, which we know today as the Vera C. Rubin Observatory.

My professor's answer was none of those. Gaia, he said immediately, referring to the European Space Agency's mission to map a billion stars. The spacecraft was months from launching, but astronomers were salivating at what it promised to yield: the largest 3D map of the Milky Way ever assembled.

Today, that promise has been fulfilled. In March of last year, the spacecraft powered down for the last time, but scientists have only begun to mine its haul of observations.

Gaia has never received the same amount of attention as some of its contemporaries. Its most valuable data don't come in the form of spectacular wallpaper-worthy images, but as astoundingly precise measurements of the positions of stars on the sky, which in turn, have yielded an unprecedented bounty of accurate distances to stars. In our cover story, Korey Haynes explains how Gaia pulled it off — and how the mission's scientific legacy is still being written.

Nearer to home, our own star continues to thrill observers with activity near the peak of solar cycle 25. With recent advancements in solar-imaging technology, more and more astroimagers have been capturing stunning images of twisting prominences, loops, and filaments. On page 40, Mark Johnston tells the story of how solar imaging got to this point — and also shares some of his own spectacular photos.

It's easy to take stars for granted. But spend some time observing them — whether in the nighttime or daytime sky — and you'll always be rewarded.

Mark Zastrow
Editor-in-Chief

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Astronauts Safe

Astronaut Jim Lovell reads the newspaper coverage of the Apollo 13 crew's safe return. NASA. AT RIGHT: CELESTRON

We welcome your comments via email to **astronomyeditorial@astronomy.com**. *Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Farewell to Lovell

Ninety-seven years! That's one hell of a run. What's even more amazing is that run took this amazing pilot, scientist, and astronaut off the planet on four of the most incredible missions in the history of humankind. I feel so very fortunate to have known Captain Jim Lovell.

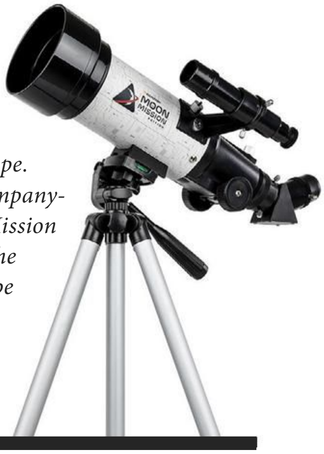
In 2018, I was able to conceive and build the monument to the Apollo 11 crew at the Kennedy Space Center. Apollo 13 is much bigger in story recognition because of the movie, so it occurred to me that it could be fairly easy to raise the money and build that monument next.

I was very grateful to meet Jim, and during that interview I got his blessing to build the Apollo 13 monument. In 2020, I literally was able to get the project funded in one week — however, that was the same week that COVID hit and the world shut down. I thought I was going to lose the monument, like Captain Lovell lost the Moon. But it was able to be constructed all the way through the pandemic, and we were able to have an unveiling with 100 people, including Jim and Fred Haise, at Space Center Houston.

Spending time with Jim was absolutely lovely. He just loved talking about all four of his missions, and was so gracious when it came to storytelling. I've met all of the moonwalkers and Jim is absolutely my favorite for many reasons, but more than anything for his kindness and his sensibility. Some people have really good hearts and really good souls, and Jim Lovell had both. Godspeed, Captain Lovell. **—Steven Barber,** project leader, Apollo 13 monument, Space Center Houston

Erratum

On our November 2025 New Products page, we described Celestron's Moon Mission Travel Scope 7 Portable Telescope. Unfortunately, the image accompanying the text was of the Moon Mission 100mm Tabletop Dobsonian; the correct photo of the Travel Scope 7 can be seen at right. Both scopes are available from www.celestron.com.



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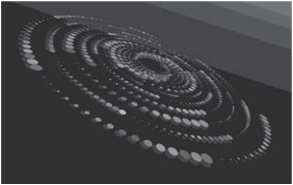

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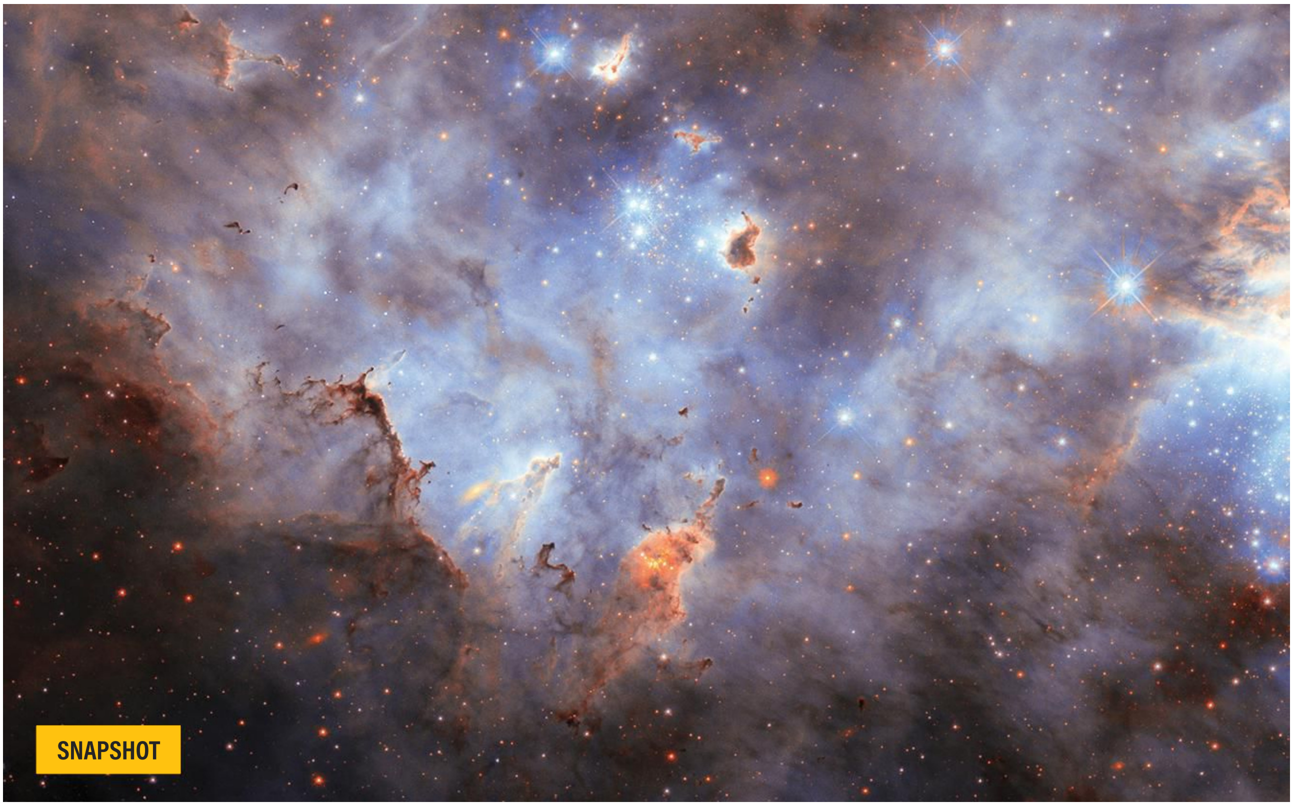
ASTRONEWS

EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH



THE LMC'S SCULPTED CLOUDS

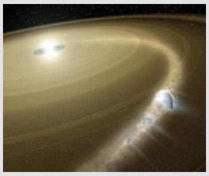
A colorful vista shows young stars shaping their surroundings.

This Hubble Space Telescope image shows a star-studded scene in the Large Magellanic Cloud (LMC), our galaxy's largest satellite, some 160,000 light-years away. The view is of young stars within the N11 star-forming region, the LMC's second-largest stellar nursery.

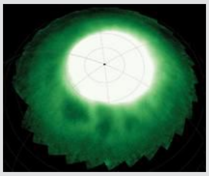
Stars are born from small portions of massive, cold clouds of gas and dust. Once a star begins to shine, its powerful photons push away any remaining material. Over time, clusters of stars can completely carve out their surroundings, resulting in a vista like the one here: a clear view of young suns lighting up the tattered remains of their birthplace. Note how the edges of the colorful clouds have been sculpted by the onslaught of intense radiation from the blue-white cluster stars.

The composite was some 20 years in the making. It combines observations of N11's stars taken by the Advanced Camera for Surveys in 2002 and 2003 with more recent Wide Field Camera 3 images of the region's dust clouds. —ALISON KLESMAN

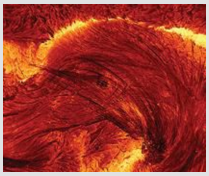
» HOT BYTES



AN ICY TREAT
Hubble watched a white dwarf, the remnant of a Sun-like star, consume icy pieces of a Pluto-like object. This surprised astronomers, as aging suns typically eject such distant, icy objects from their systems.



BEADS AND STARS
JWST saw two new structures in Saturn's upper atmosphere: dark beads (pictured above) and a star-shaped pattern. Despite occurring at different heights, their positions line up, suggesting they may be linked.



DARK RIBBONS
On Aug. 8, the Daniel K. Inouye Solar Telescope imaged its first X-class solar flare. It saw hundreds of dark strands of dense plasma called coronal loops — some just 15 miles (25 km) thick.

ESA/HUBBLE & NASA, C. MURRAY, J. MAÍZ APELLÁNIZ. BOTTOM FROM LEFT: T. PYLE (CALTECH, NASA'S JET PROPULSION LABORATORY; NASA/ESA/CSA/STALLARD ET AL 2025; NSF/NSO/AURA

STRONGEST EVIDENCE YET FOR PAST LIFE ON MARS

A peer-reviewed paper adds weight to the claim that the Cheyava Falls rock may hold the signatures of ancient martian microbes.

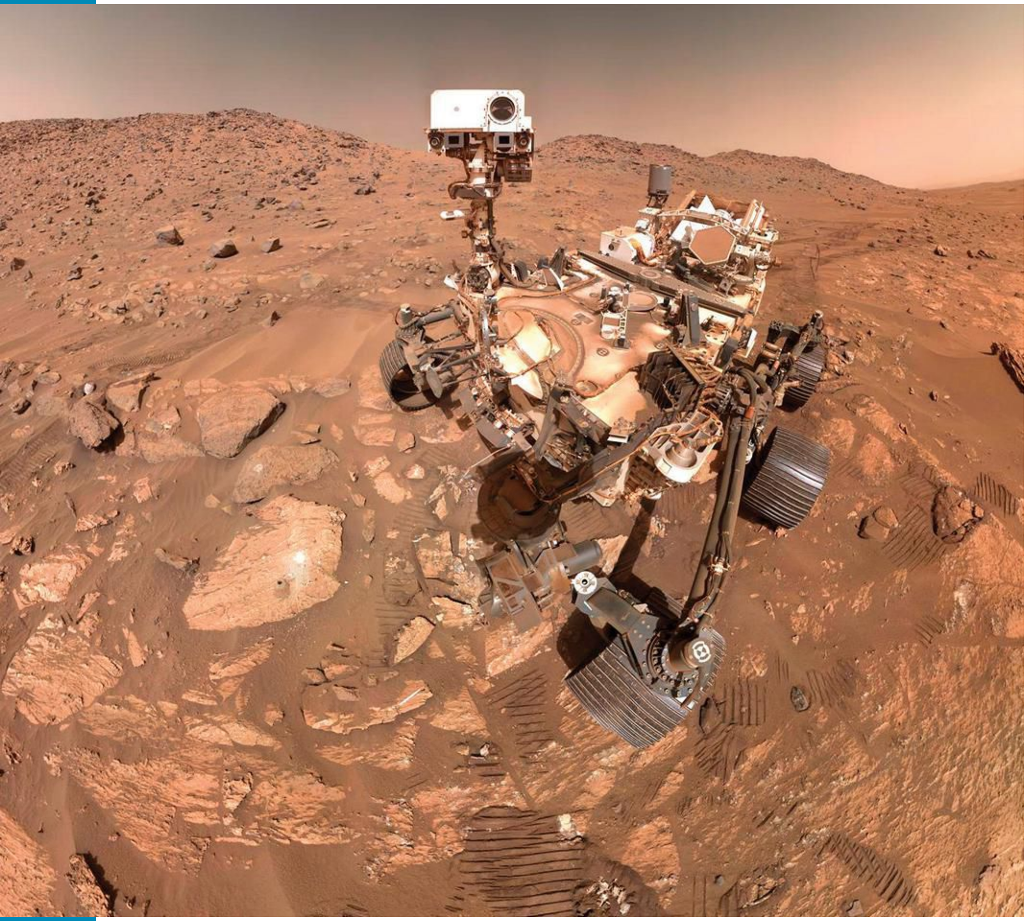


PHOTO PROOF. Perseverance took this selfie July 23, 2024. To the rover's left near the center of the image is the arrowhead-shaped Cheyava Falls rock. The small dark hole in the rock is where Perseverance took a core sample, now in a sample tube stored in the rover's belly. NASA/JPL-CALTECH/MSSS

» At a Sept. 10 press conference, NASA announced its Perseverance Mars rover had discovered a "potential biosignature." The signature requires further study, scientists say, but it represents the most compelling evidence yet for ancient microbial life on Mars.

The findings were detailed in a paper published the same day in *Nature* and led by Joel Hurowitz, a planetary scientist at Stony Brook University in New York. The paper centers on a spotted rock named Cheyava Falls, which contains organic molecules and minerals strongly associated with microbial biological processes. The rock was found in Neretva Vallis, a dry river valley that once fed an ancient lake at Jezero Crater.

NASA shared images of the discovery last summer. But a more detailed analysis has now survived formal peer review — an important step in confirming the evidence.

A SURPRISING DISCOVERY

The discovery required the use of multiple instruments in Perseverance's toolkit. First, organics in the rock were identified by the Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) instrument. SHERLOC detected a "smoking gun indicator for the presence of organic matter in this mud," according to Hurowitz. As a result, the team used one of the rover's limited tubes to collect a sample they named Sapphire Canyon.

Then the team turned to the Planetary Instrument for X-ray Lithochemistry (PIXL) to map the spots' chemical composition. PIXL revealed the areas were rich in iron-phosphate (likely vivianite) and iron-sulfide (likely greigite) minerals. The paper posits that these could be the waste products left by ancient microbes, which used the organic material as an energy source. By taking electrons from the organic matter and transferring them to iron and sulfate minerals, they created the vivianite and greigite via a process known as a redox reaction.

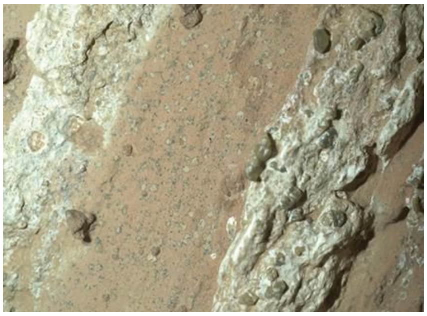
Adding to the intrigue is the rock's age: some 2 billion to 3 billion years old. Scientists have long believed Mars' habitable window was around 4 billion years ago, when the planet had a thicker atmosphere, more water, and a protective magnetic field. The younger age of Cheyava Falls raises the possibility that this window was open longer.

WEIGHING THE EVIDENCE

The limitations of remote science mean

scientists cannot unequivocally confirm the presence of a biosignature. The same minerals could form abiotically (without life) under high heat, although the surrounding rock shows no evidence of having been "cooked," Hurowitz explained. "When we see features like this in sediment on Earth, these minerals are often the byproduct of microbial metabolisms. … But there are nonbiological ways to make these features that we cannot completely rule out."

In an independent *Nature News & Views* commentary, Janice Bishop, a chemist and planetary scientist at the SETI Institute, and Mario Parente, an associate professor at the University of Massachusetts Amherst, suggest the features could have formed without life over long geological timescales.



LEOPARD SPOTS. The so-called leopard spots of the Cheyava Falls rock are captured in this image taken July 18, 2024. The spots are possible indicators of past chemical reactions that could be associated with life. NASA/JPL-CALTECH

FUTURE UNCERTAINTY

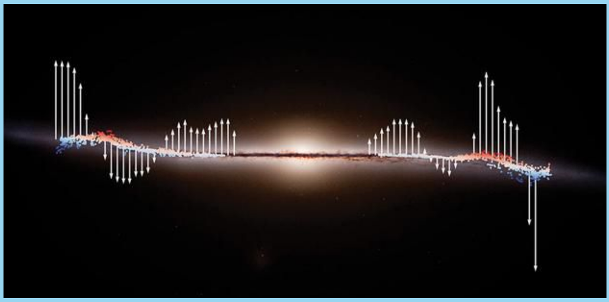
Ultimately, the final answer lies on Mars, locked inside the Sapphire Canyon sample tube. The finding adds urgency to the Mars Sample Return (MSR) mission to retrieve Perseverance's samples, which NASA was developing with the European Space Agency.

The Trump administration's FY 2026 budget request called for an end to the MSR mission, zeroing out its funding. "We believe there's a better way to do this, a faster way to get these samples back," Sean Duffy, acting NASA administrator, said during the press conference.

When asked by a reporter whether the findings would reshuffle the administration's priorities for returning samples, Duffy said the rover's findings did not "change the mission," but were "consistent with the president's vision and mission of continuing the science to support human exploration beyond Earth." —BROOKS MENDENHALL

GAIA SEES A GREAT WAVE

LIKE A CROWD performing "the wave" in a stadium, stars are rippling through our Milky Way Galaxy's warped disk, pictured here in an edge-on view that illustrates the newly discovered "great wave." The colored dots map the positions of stars: Red dots represent stars above the galactic plane, while blue indicates those below it, together tracing the wave's undulation. The white arrows depict the vertical motion of these stars. An interesting characteristic, revealed by data from the European Space Agency's Gaia space telescope, is that the pattern of motion (the arrows) is slightly shifted from the pattern of stellar positions (the colored dots). The stars with the largest vertical motion are those just starting to ripple upward, and not those already at the wave's crest. This is expected from a propagating wave — as in the stadium, people just starting to stand have the most vertical motion. —B.M.



ESA/GAIA/DPAC, S. PAYNE-WARDENAAR, E. POGGIO ET AL (2025)

QUICK TAKES

MESSY EATER

New observations from the NASA/JAXA XRISM satellite of a stellar-mass black hole pulling material from a companion star showed that, confounding expectations, the black hole was not more efficient at gobbling material when matter flowed onto it more slowly versus more quickly.

MAKING MERCURY

A study published June 27 in *Nature Astronomy* suggests that the planet Mercury may have been formed in a grazing collision of two similarly sized planetesimals, rather than being the leftover core of a much larger planet that underwent a major impact, as previously thought.

NEED A BOOST?

In September, NASA awarded Katalyst Space Technologies $30 million to boost the Neil Gehrels Swift Observatory to a higher orbit within 10 months. The telescope is experiencing faster-than-expected orbital decay due to intense solar activity, which swells our atmosphere and increases drag on orbiting satellites.

THROUGH THICK AND THIN

Initial JWST observations indicate exoplanet TRAPPIST-1 e does not have a thick, carbon dioxide-rich atmosphere. However, scientists cannot rule out the possibility that the rocky world — which lies in its star's habitable zone — might have enough of the greenhouse gas to maintain some liquid water.

WARM SPELL

Data from NASA's Dawn mission show the decay of radioactive elements in the core of dwarf planet 1 Ceres could have supported long-lasting hydrothermal activity — and thus potentially habitable conditions lasting for hundreds of millions of years. —A.K.

HAYABUSA2, TARGET ASTEROID ARE OF A SIZE

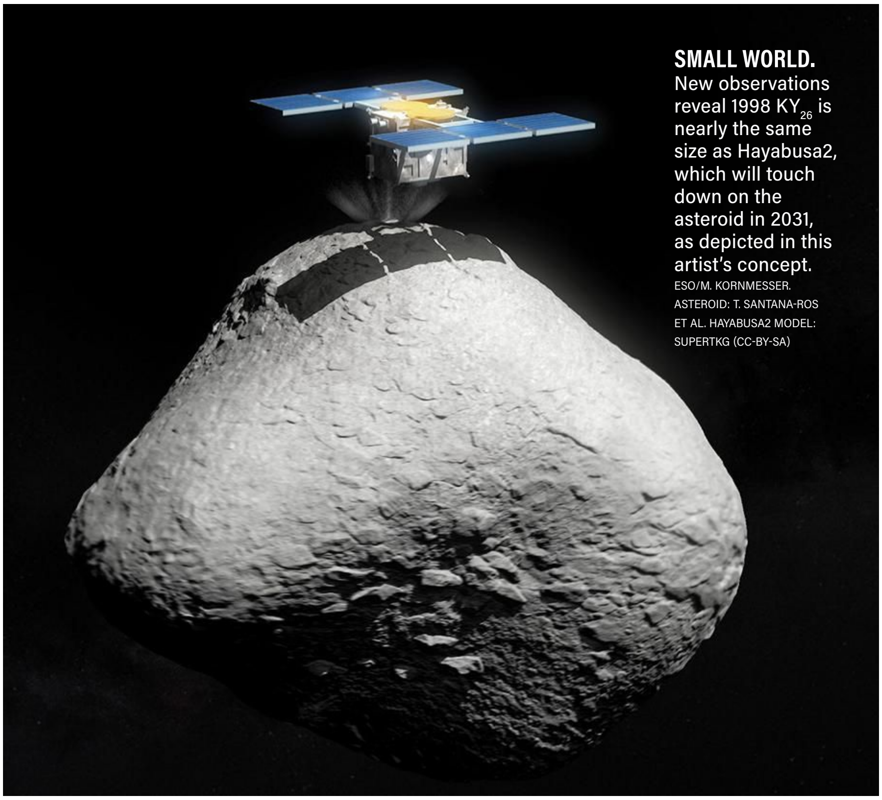
AFTER DROPPING OFF samples of asteroid 162173 Ryugu in December 2020, the Japan Aerospace Exploration Agency's (JAXA) Hayabusa2 is now on course to fly past asteroid 2001 CC_{21} later this year before rendezvousing with 1998 KY_{26} in 2031.

The latter encounter just got more interesting. A paper published Sept. 18 in *Nature Communications* revealed that 1998 KY_{26} is smaller and rotating more quickly than initially thought. New data taken by ground-based telescopes during 1998 KY_{26}'s close approach to Earth in 2024 show it is just 36 feet (11 meters) across. That's one-third the size of previous estimates and on par with Hayabusa2 itself. While the spacecraft's body measures just 5.2 feet by 3.2 feet by 4.1 feet (1.6 m by 1 m by 1.25 m), with solar panels it is nearly 20 feet (6 m) across. Additionally, 1998 KY_{26} is rotating every 5.4 minutes, twice as fast as the previously measured value.

Hayabusa2 is aiming to briefly touch down on 1998 KY_{26} in a similar manner to its visit to Ryugu. But 2,960-foot (900 m) Ryugu spins once every 7.6 hours. On tiny, fast-spinning 1998 KY_{26}, the maneuver will be a totally different ballgame. "The smaller size and faster rotation now measured will make Hayabusa2's visit even more interesting, but also even more challenging," said European Southern Observatory astronomer and study co-author Olivier Hainaut in a press release.

The asteroid's small size and fast spin also have implications for its structure. Although it could be a so-called rubble-pile asteroid like Ryugu, made of accumulated smaller bits of debris, astronomers can't rule out the possibility that 1998 KY_{26} is solid rock — a single piece of a larger body that was thrown out during a collision. "We have never seen a 10-meter-size asteroid in situ, so we don't really know what to expect and how it will look," said study first author Toni Santana-Ros of the University of Alicante, Spain.

While 1998 KY_{26} is not considered a hazard, there are 2,508 currently known objects with orbits close enough to our planet to raise concerns. The new measurements demonstrate the ability of current technology to characterize small asteroids, bolstering future planetary defense efforts as we seek to understand the objects — particularly the small, stealthy ones — that populate our neighborhood. –A.K.



SMALL WORLD. New observations reveal 1998 KY_{26} is nearly the same size as Hayabusa2, which will touch down on the asteroid in 2031, as depicted in this artist's concept. ESO/M. KORNMESSER. ASTEROID: T. SANTANA-ROS ET AL. HAYABUSA2 MODEL: SUPERTKG (CC-BY-SA)

ASTRID ECKERT/TUM

RING LASER TRACKS EARTH'S WOBBLE

A 250-DAY experiment at the Technical University of Munich Institute of Engineering for Astronomical and Physical Geodesy in Germany has improved 100-fold our ability to measure changes in the wobble of Earth's axis as our planet spins. The team utilized a ring laser, which sends light along two different paths, bouncing each beam off a mirror so they come together at a single point to create a pattern of interference that changes depending on Earth's rotational speed. The result will allow scientists to model our planet's motion through space with unprecedented accuracy. –A.K.

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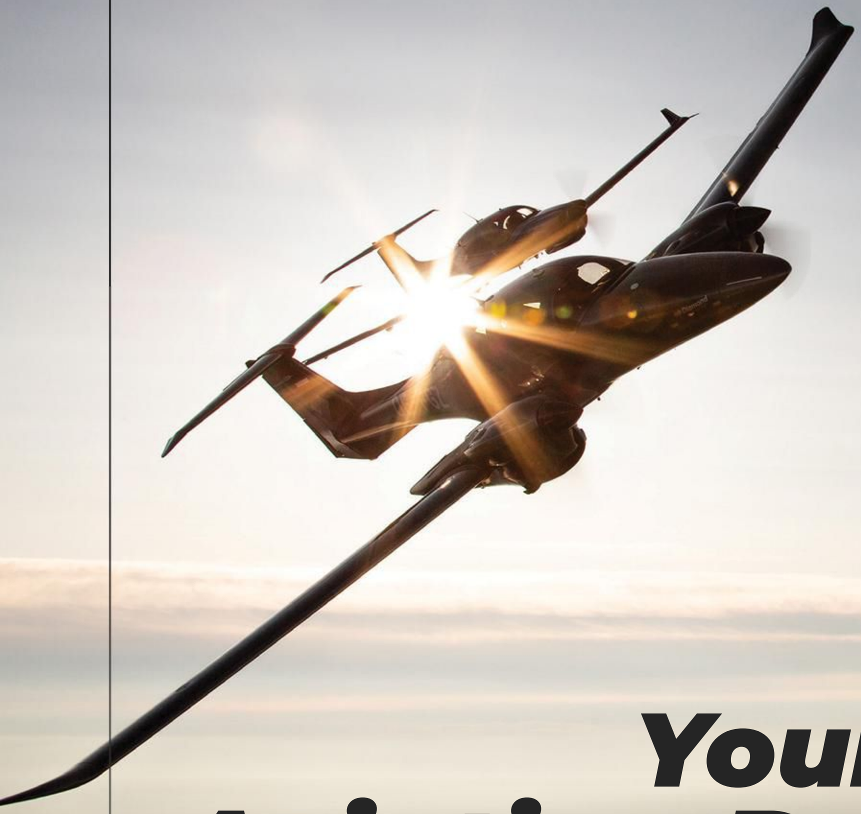

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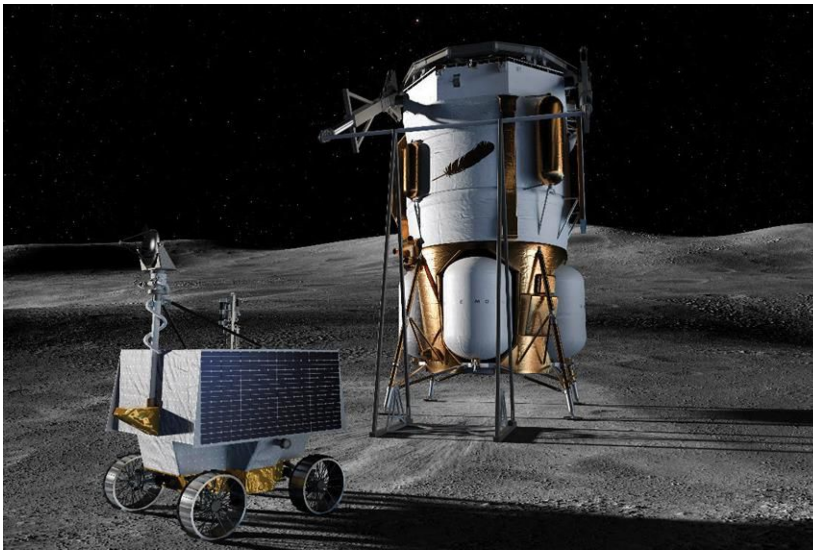


NEW RIDE. Blue Origin's Blue Moon Mark 1 lander (center) and NASA's VIPER (foreground) stand on the lunar surface in an artist's depiction. BLUE ORIGIN

NASA REVIVES VIPER WITH BLUE ORIGIN CONTRACT

NASA IS REVIVING its Volatiles Investigating Polar Exploration Rover (VIPER), and has awarded Blue Origin a contract to deliver it to the Moon's south pole in 2027.

The task order, awarded Sept. 19 under the Commercial Lunar Payload Services (CLPS) program, gives the previously canceled half-billion-dollar machine a second chance and offers Jeff Bezos' company an opportunity to prove its deep-space capabilities.

The CLPS initiative is part of NASA's strategy to foster a commercial space economy. Under the program, NASA buys delivery services from American companies that rapidly send payloads to the lunar surface.

VIPER was canceled in 2024 despite the vehicle being fully built, with NASA citing "cost increases, delays to the launch date, and the risks of future cost growth." It had included a $199.5 million contract with commercial firm Astrobotic. The company's Griffin lander is now slated to carry the FLEX Lunar Innovation Platform (FLIP) rover from Astrolab to the lunar south pole instead. FLIP will field test systems for the company's upcoming line of larger, customizable modular Flexible Logistics and Exploration (FLEX) rovers.

At the time of cancellation, NASA said it would consider proposals from commercial organizations to launch and operate VIPER if it came at no cost to the government.

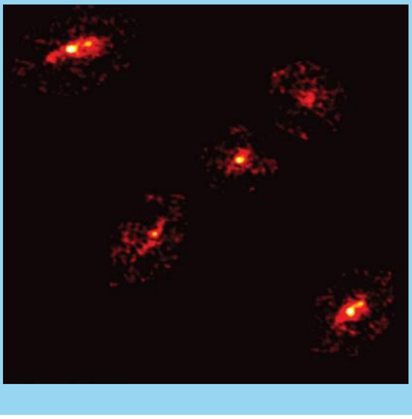
The Blue Origin contract, with a total potential value of $190 million, reverses that stance, but is structured to shield the agency from cost overruns and delays. The task order requires Blue Origin to plan the payload integration and demonstrate how the rover will be offloaded onto the lunar surface, with an option to perform the landing following review and if Blue Origin completes a lunar landing with its Blue Moon Mark 1 lander. Blue Origin launched its New Glenn rocket for the first time in January 2025, but has yet to attempt a MK1 landing.

VIPER is designed to navigate and prospect for ice in unexplored shadowed craters untouched by sunlight for billions of years. This ice is a crucial resource, potentially providing drinking water, breathable air, and rocket propellant for future astronauts. –B.M.

80% The potential reduction in Europe's need for land-based renewable energy achievable by launching solar panels into geostationary orbit.

AN ODD EINSTEIN CROSS

EINSTEIN CROSSES occur when light from a faraway galaxy is bent, or lensed, by a group of galaxies that sits between the more distant object and Earth. This distorts the light into four separate images, called an Einstein cross. But this image of the galaxy HerS-3, located 11.6 billion light-years away, is odd — literally. Its Einstein cross has five points, or images, including one in the middle. Astronomers modeling the foreground galaxy group determined the only way to create this fifth image was to add more mass than is visible in the galaxies alone. This suggests they are surrounded by a dark matter halo several trillion times the mass of the Sun, showing how strange effects like gravitational lensing can reveal massive structures invisible to our telescopes. –A.K.



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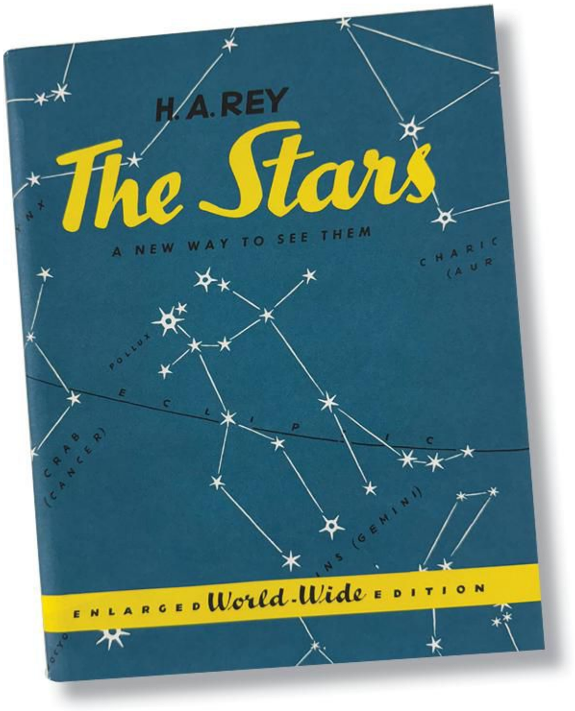


H.A. Rey's *The Stars: A New Way to See Them* was an indisputable favorite, suggested by many of the readers who wrote in. Editor-in-Chief Mark Zastrow also named it as his pick for an influential beginner's guide. RAYMOND SHUBINSKI

Beginner's book tour

The September 2025 issue featured "A guide to beginner's guides," a reminiscence and description of some the books for astronomy beginners that Contributing Editor Raymond Shubinski recommends or considers influential. Our readers responded with a flood of emails adding their own suggestions to his list.

Is your favorite mentioned here? What books are we still overlooking?

"Back in 1973, my neighbor was cleaning out an attic space and had a pile of stuff for the garbage. A book titled *Making Friends With the Stars* caught my eye. I was engrossed in this book for the next several months. It showed how seasonal constellations change, described all the effects of 23.5° tilt, the ecliptic, zodiac, orbits, eclipses, planets — I was hooked at age 11 for life."

— Benito Rivera

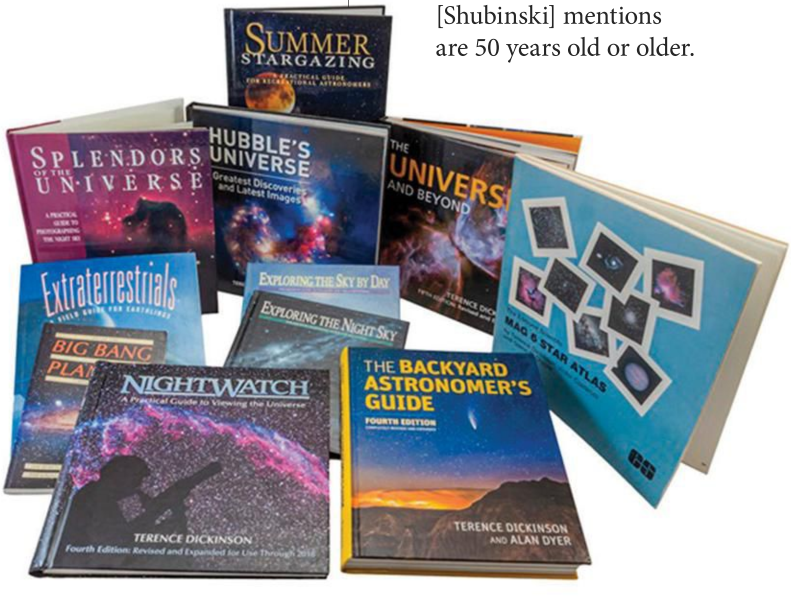
MOST RECOMMENDED BOOKS

As we read through the many emails, some themes emerged: Several readers agreed with the recommendation of Patrick Moore's guides, for instance. But beyond Shubinski's list, four titles came up more often than all the rest.

The Stars: A New Way to See Them, by H.A. Rey
"It shows the constellations as stick figures that once seen, are impossible to unsee. It was meant for 6th grade students, but the scientific descriptions are complex enough to please adults." **—Anna Tyner**

"The book basically redrew constellations so that they looked much more like the mythological objects they were supposed to depict than any other publication I have seen since." **—Charley Tichenor**

NightWatch: A Practical Guide to Viewing the Universe, by Terence Dickinson, and ***The Backyard Astronomer's Guide***, by Terence Dickinson and Alan Dyer
"Most of the books [Shubinski] mentions are 50 years old or older.



Terence Dickinson, who passed away in 2023, was a prolific author of books for astronomy enthusiasts — as well as a former *Astronomy* editor. *NightWatch* and *The Backyard Astronomer's Guide* (co-authored with Alan Dyer) were among the books most recommended by our readers. ALAN DYER

"I was 8 years old and purchased my very first book at our elementary school's annual book fair — *Fun With Astronomy*, by Mae and Ira Freeman. I'm now 76, retired with a Ph.D. in molecular biology, and can honestly say that book inspired my interest in science in general and my hobby of visual observations and astrophotography with my Celestron Evolution 8." —Richard Montagna

STAFF PICKS

What books prompted a lifelong interest in the sky for the *Astronomy* staff? Here are our editors' picks for their favorite beginner's guides or the books that influenced them most as young astronomers.

MARK, EDITOR-IN-CHIEF:
The Stars: A New Way to See Them, by H.A. Rey

ALISON, SENIOR EDITOR:
Star Maps for Beginners: 50th Anniversary Edition, by I.M. Levitt and Roy K. Marshall

MICHAEL, ASSOCIATE EDITOR:
1,001 Questions Answered About Astronomy, by James S. Pickering

ELISA, SENIOR PRODUCTION EDITOR:
The New Patterns in the Sky: Myths and Legends of the Stars, by Julius D.W. Staal

ALSO ON THE SHELF

Here are some of the other titles suggested — while they may have come up less frequently, they still got a lot of love from their readers!

How to Use Your Telescope, by Sam Brown
"It was the textbook that laid the foundation for selection and use of all of my further telescopes." **—Charley Tichenor**

Sky Guide: A Field Guide for Amateur Astronomers, by Mark R. Chartrand III
"Apparently I used to take it everywhere because it's totally marked up and held together with a rubber band and tape!" **—Gary Auth**

365 Starry Nights, by Chet Raymo
"A night-by-night guide with hand-drawn illustrations and easily followed text describing what is up — every night of the year!" **—Gary Auth**

A Field Guide to the Stars and Planets, by Donald H. Menzel
"I loved the Photographic Atlas Charts, where the right-hand page showed a photo of a portion of the sky, and the left page showed a negative image of the same photo, with simple constellation lines drawn and stars and deep sky objects labelled. The photos were made from plates taken at the Harvard College Observatory, over which the author presided." **—Mark Lancaster**

What's Out Tonight?, by Ken Graun
"The charts are a perfect balance between 'Plot Plan' and 'Detail Drawing.' I use it more than Sky Safari and my *Pocket Sky Atlas*." **—Michael A. Gebauer**

1001 Questions Answered About Astronomy, by James S. Pickering
"The content was wonderful. I do wish someone would publish an updated version, organized in the same way." **—Kevin Alcott**

Deep Sky Objects: A Photographic Guide for the Amateur, by Jack Newton
"A catalog of the Messier objects, with tips on how to find them in the night sky, and black-and-white photographs accompanying each entry." **—Kevin Alcott**

Star Maps for Beginners, by I.M. Levitt and Roy K. Marshall
"In addition to the maps, I especially liked the page 'Where to Find the Planets' which showed where Venus, Mars, Jupiter, and Saturn were. This book was a cherished resource for me when starting out, and I spent many hours observing with my white Tasco telescope." **—Gary Cadle**

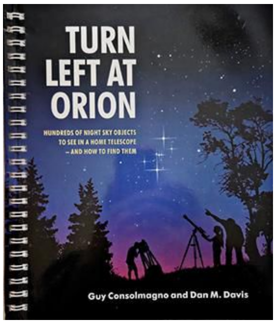
Consider what's changed in the field of astronomy in that time! How about [Dickinson's] books, which are much more current?" **—William M. Arden**

"I learned a lot from *The Backyard Astronomer's Guide*." **—George Reynolds**

"I consider *NightWatch* a lot more practical [than some other guides] for use at the telescope. And there is *The Backyard Astronomer's Guide*, which I recommend to any person who just getting into the hobby. I read the most recent edition cover to cover when I bought it. It is a great book for anyone at any level of skill." **—Dan Carey**

Turn Left at Orion, by Guy Consolmagno and Dan M. Davis
"An indispensable guide for beginners with small telescopes." **— Kevin Alcott**

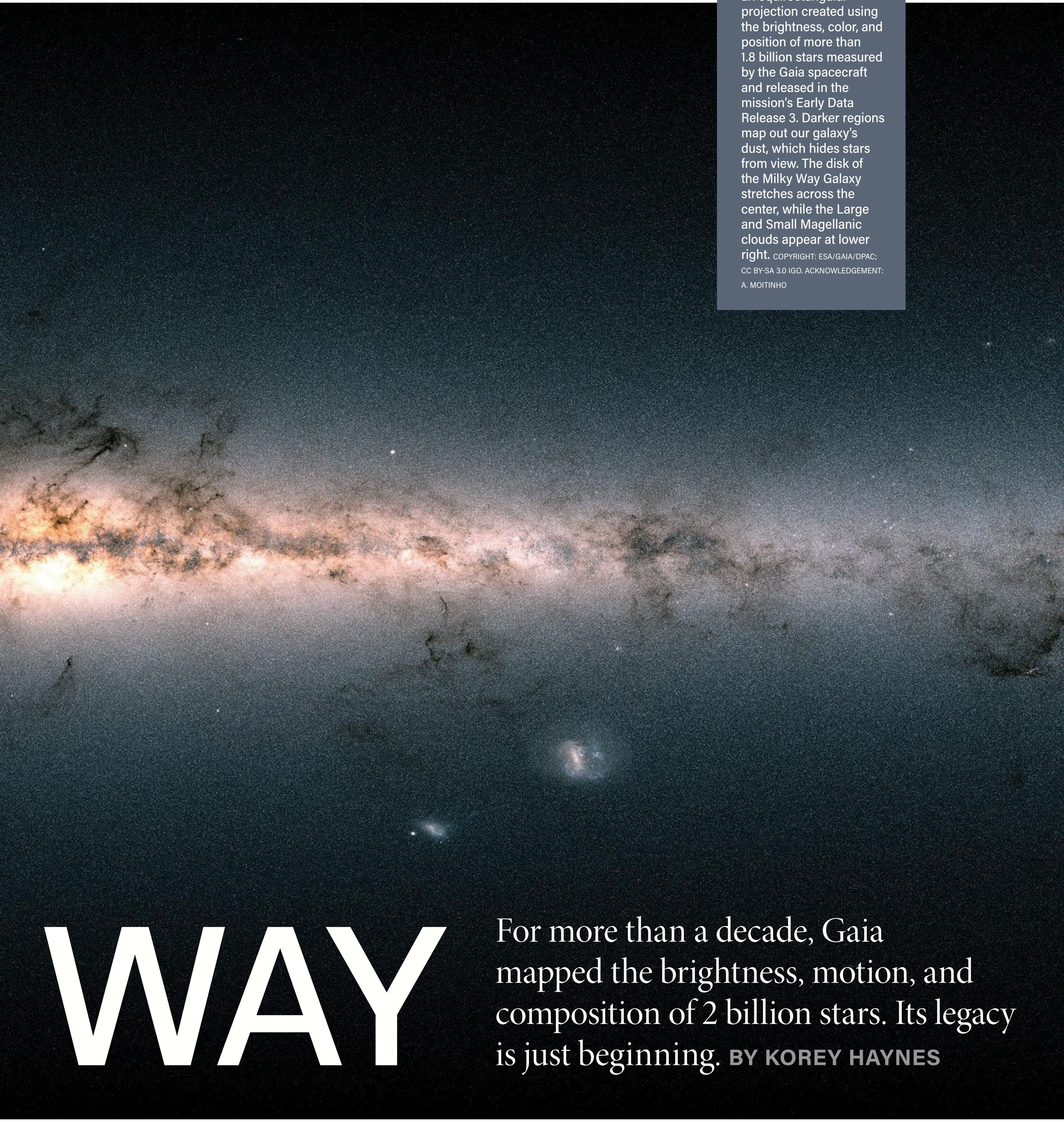
"[One of] my favorite books was *Turn Left at Orion* by Guy Consolmagno and Dan Davis." **—George Reynolds**


TURN LEFT AT ORION
HUNDREDS OF NIGHT SKY OBJECTS TO SEE IN A HOME TELESCOPE —AND HOW TO FIND THEM
Guy Consolmagno and Dan M. Davis

When Glenn Chaple named some of his favorite beginner's guides in his Observing Basics columns in the March and April 2020 issues, readers were quick to let him know the books they felt he'd overlooked. Among them was *Turn Left at Orion*, which several readers also flagged as missing from Shubinski's September 2025 article. GLENN CHAPLE

"I am a retired planetarium educator. As often as I was asked to recommend telescopes for gifts, beginner guides to the skies followed immediately behind. Among those I recommend are H.A. Rey's *The Stars: A New Way to See Them*, Chet Raymo's *365 Starry Nights*, and Terence Dickinson's *NightWatch*. It has been my experience that potential stargazers become easily frustrated when trying to locate constellations. Each of these books in their own way makes the night sky a comfortable, friendly, and easy-to-navigate place." —John C. Scala

How Gaia revealed THE MILKY



This all-sky map is not a photo; rather, it is an equirectangular projection created using the brightness, color, and position of more than 1.8 billion stars measured by the Gaia spacecraft and released in the mission's Early Data Release 3. Darker regions map out our galaxy's dust, which hides stars from view. The disk of the Milky Way Galaxy stretches across the center, while the Large and Small Magellanic clouds appear at lower right. COPYRIGHT: ESA/GAIA/DPAC; CC BY-SA 3.0 IGO. ACKNOWLEDGEMENT: A. MOITINHO

WAY

For more than a decade, Gaia mapped the brightness, motion, and composition of 2 billion stars. Its legacy is just beginning.

BY KOREY HAYNES

This "image" of the Large Magellanic Cloud is not a photo, but a combination of Gaia's measurements of stars' brightness and color (using various filters) to create a view of this Milky Way satellite. Gaia data have strongly indicated the LMC hosts a supermassive black hole in its center, much like larger galaxies do. ESA/GAIA/DPAC, CC BY-SA 3.0 IGO. ACKNOWLEDGEMENT: GAIA DATA PROCESSING AND ANALYSIS CONSORTIUM (DPAC); A. MOITINHO/A. F. SILVA/M. BARROS/C. BARATA, UNIVERSITY OF LISBON, PORTUGAL; H. SAVIETTO, FORK RESEARCH, PORTUGAL

On Jan. 15, 2025, the Gaia spacecraft took its last image. Then the craft ran a final round of engineering tests, fired its thrusters to leave Earth behind, and slipped into an orbit around the Sun, finally turning off on March 27.

After more than a decade in operation, 3 trillion observations, and 2 billion stars observed, Gaia has earned its retirement. Launched by the European Space Agency (ESA) in 2013, Gaia's goal was "to map a billion stars," and it succeeded.

Compiling the map of where these stars are and how they move paints a picture of our entire galaxy — even the dark matter, whose gravitational influence subtly tugs on the stars. Along the way, Gaia found brown dwarfs, exoplanets, and quasars. Peering down to 20th magnitude, Gaia also spied stars in the Milky Way's satellite galaxies, the small stellar cities that orbit just outside our own, to reveal how they interact with our galaxy now and in the distant past.

Though Gaia's observations are complete, scientists are still analyzing the hundreds of terabytes of information sent from space. And the Gaia data are being released to the public in stages, as is common for most large, long-lasting surveys. But the data are already proving wildly useful, informing the science of exoplanets, black holes, and more. The survey has thus far uncovered new information about ancient collisions that sculpted the Milky Way, honed our picture of its current shape, discovered an exoplanet, and potentially revealed the central black hole in a neighboring galaxy. And that's with just the first three years of data. More discoveries are sure to come.

The Gaia mission will return new discoveries for years, most likely decades to come. But its accomplishments thus far have already blown open our understanding of the Milky Way, both past and present.

An impressive assignment

The Gaia spacecraft was responsible for obtaining the most precise measurements ever of more than a billion stars' positions, distances, and motions. This catalog was meant to stand on the shoulders of Hipparcos, a spacecraft launched in 1989 with a similar mission. That satellite produced high-precision data for some 118,000 stars and lower-precision

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On March 27, 2025, operators in Darmstadt, Germany, sent their final commands to the Gaia spacecraft, instructing it to shut down its computer and communications systems, then move from L2 into its retirement orbit around the Sun. ESA data for 2.5 million stars. Gaia outstripped its predecessor by a factor of a thousand, while taking measurements 200 times more precise.

Gaia was conceived as part of ESA's Horizon 2000+ campaign, a long-term development guide similar to the Decadal Survey used by American space research agencies. First proposed in 1993, Gaia was officially confirmed in 2000. Constructed by several European partners, the Gaia spacecraft was completed in June 2013. Originally scheduled for a November launch that year, the mission was briefly delayed when ESA officials decided to replace two transponders, which had proved faulty in a different spacecraft already in orbit.

Gaia ultimately launched smoothly from Korou, French Guinea, aboard a Soyuz rocket and Fregat upper stage on Dec. 19, 2013. The craft spent four days in a temporary orbit near Earth to deploy its sunshield and undergo tests before launching on a 30-day cruise out to the 930,000-mile (1.5 million kilometers) distant Earth-Sun Lagrange 2 point (L2), a common orbital destination for telescopes requiring exceptionally cold and dark views of space. Gaia would then spend its lifetime on a 180-day orbit around this spot. The telescope saw first light a week before reaching its final destination, imaging roughly 18,000 stars over the course of three hours on Jan. 8, 2014, and even measuring its first parallax, of the star Sadalmelik (Alpha [α] Aquarii).

Gaia carried two twin telescopes, each with a primary mirror about 7.5 square feet (0.7 square meter); for comparison, the James Webb Space Telescope's mirror covers some 270 square feet (25 m^2). But Gaia had a total of 10 mirrors, which reflected light back and forth on a path 115 feet (35 m) long in order to focus the light on its sensitive detectors, feeding into three instruments. An astrometric instrument measured the position and movements of stars on the two-dimensional sky (which, over time, allowed astronomers to derive a star's distance). A photometric instrument recorded

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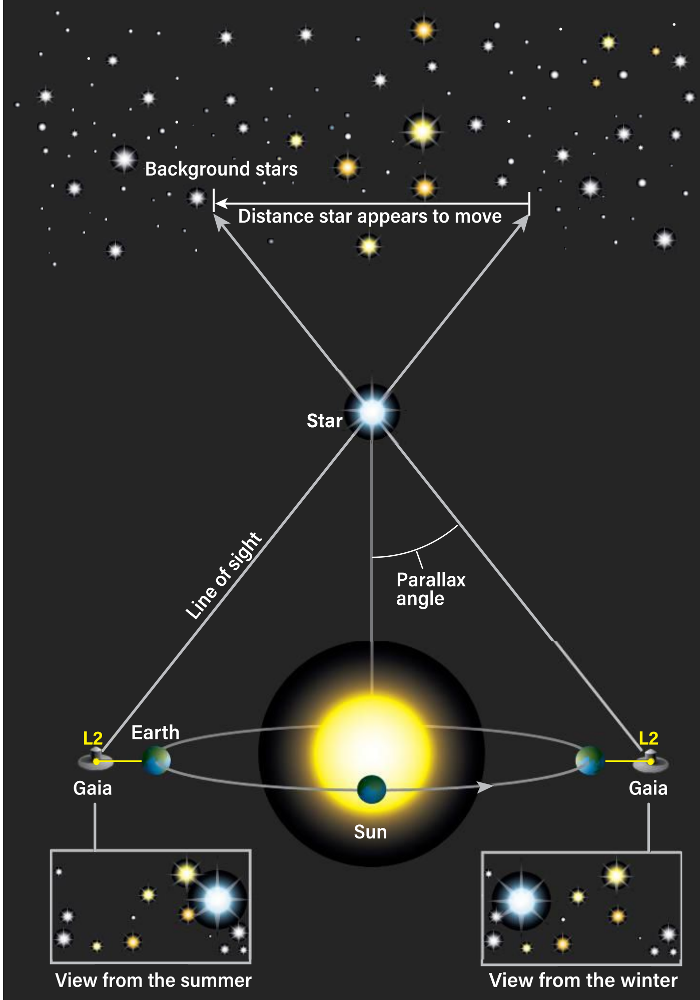
MEASURING PARALLAX

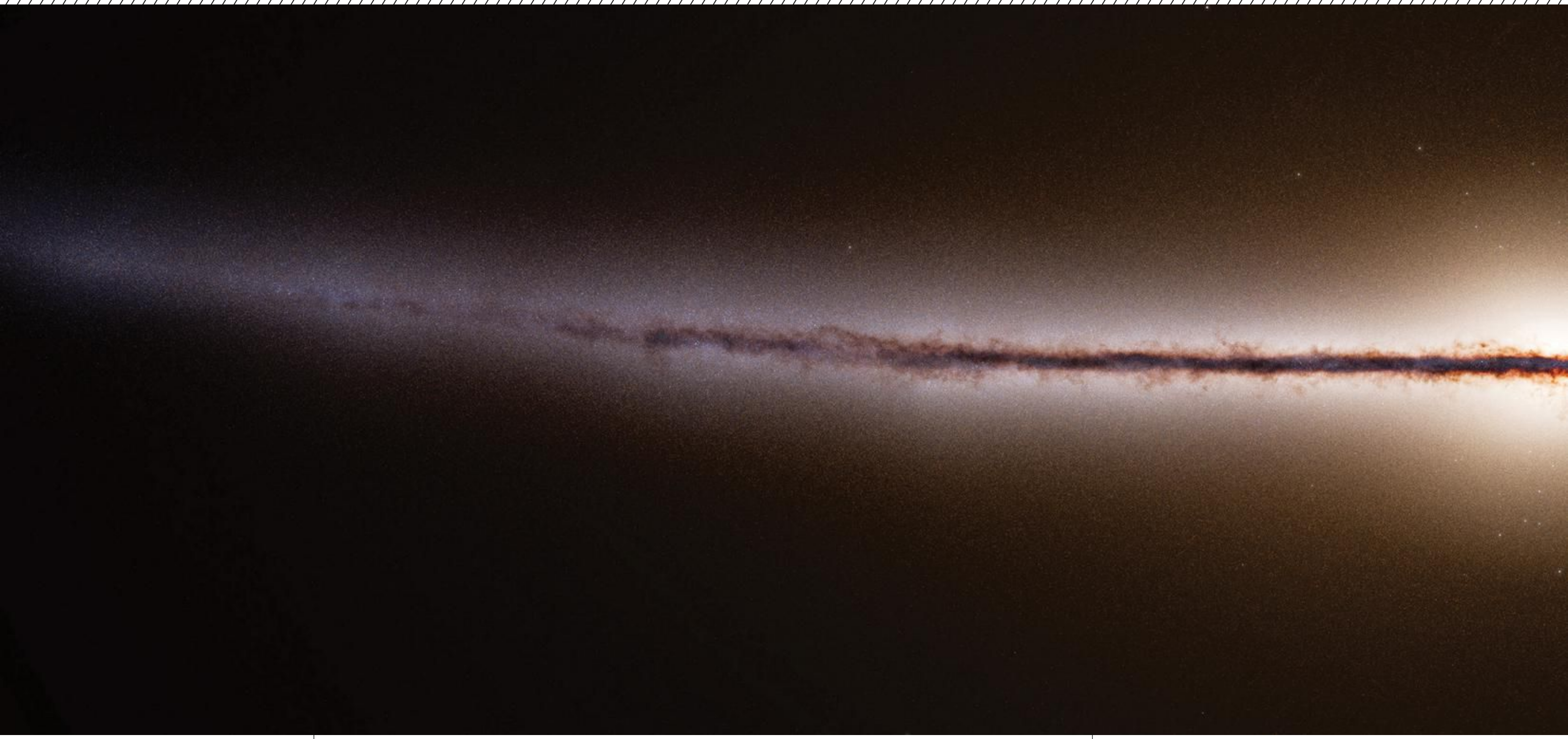


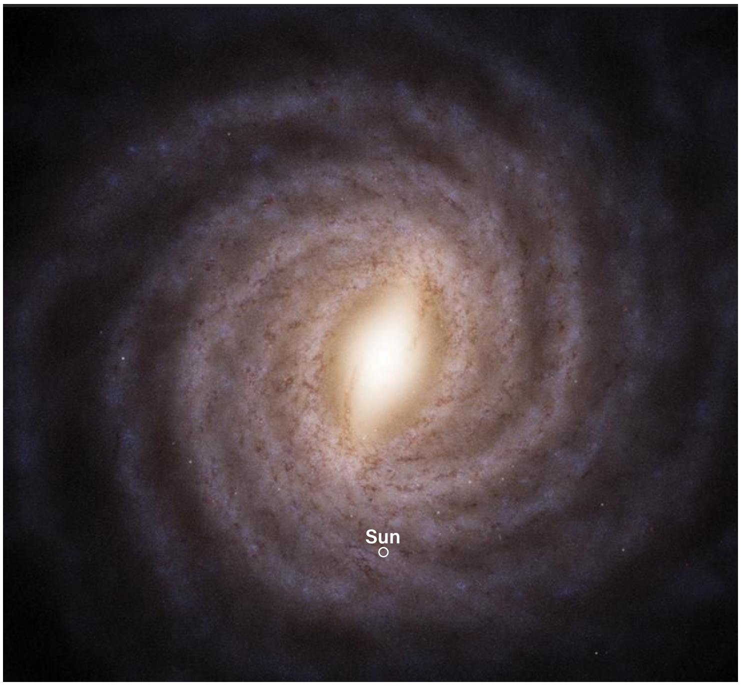
ASTRONOMY: ROEN KELLY

From its position at Earth's L2 point, Gaia circled the Sun once a year along with our planet. As it did so, its position changed by some 186 million miles (300 million km) over the course of a year. By observing the same stars while on opposite sides of the Sun, Gaia used a technique called parallax to determine their distance.

As an observer's position changes, nearer objects appear to move with respect to more distant ones. In this case, nearer stars appear to move more on the sky than farther suns when viewed six months apart, from opposite sides of Earth's orbit. The two different sightlines to the same star — one on either side of our orbit — create a triangle, and the parallax angle is defined as half the angle of that triangle's apex. By measuring the parallax angle of a given star, astronomers can use trigonometry to work out its distance.

A parallax angle of exactly 1 arcsecond (1") means a star is approximately 3.26 light-years away — a distance defined as a parsec (from the terms "parallax" and "arcsecond"). Gaia was capable of measuring changes in star positions down to 0.000001" over the course of a year. *— Alison Klesman*





↑→ From our planet's location inside the Milky Way, we cannot fly outside the galaxy to view what it looks like. By measuring the positions of billions of stars, however, Gaia has produced the most accurate maps of the Milky Way to date. These artist's renderings show our galaxy from above (right) and the side (top), allowing astronomers to better understand its size, shape, and detailed structure. We now know the Milky Way is a barred spiral with multiple arms, and that its disk is not flat but warped, with one edge curving above the center and the other turned down below it. ESA/GAIA/DPAC, STEFAN PAYNE-WARDENAAR – CC BY-SA 3.0 IGO (2)

their colors (which tell us a star's temperature, mass, and composition). And a spectroscopic instrument measured the Doppler shift of stars, recording their radial motions toward and away from Earth.

The astrometric instrument was Gaia's bread and butter. Like Hipparcos before it, Gaia's two telescopes peered at two fields of view simultaneously, building up a catalog of the relative separation of stars on the sky to allow unprecedented precision in their positions. The two telescopes always pointed 106.5° apart as the craft rotated in a circle every six hours, one telescope trailing the other. The spacecraft was also inclined 45° from the Sun, precessing around that axis every 63 days. The combination of movements allowed Gaia to view each of its 2 billion targets, scattered across the whole sky, roughly 14 times a year.

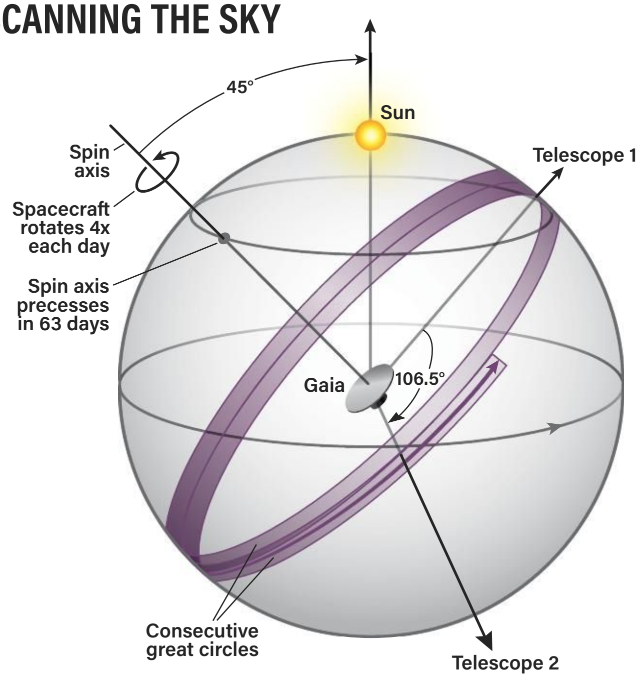
An often surprising aspect of astronomy is that it is extraordinarily difficult to measure the distance of objects in space. In fact, there's only one direct method, called parallax, which measures the apparent change in position of a nearby object compared to one that is more distant, which appears fixed. (See the sidebar "Measuring parallax" on page 17 for more details on how parallax works.) Gaia obtained parallax measurements of a billion objects, some 99 percent of which had never been accurately measured before.

A huge amount of Gaia's mission was aimed toward a better understanding of our home galaxy, the Milky Way. It's a bizarre twist that while astronomers can observe thousands of nearby galaxies, mapping their stars, dust lanes, ripples, and bulges, producing breathtaking images along the way, we can't take a

simple picture of our own galaxy. But by obtaining precise distance and position measurements of billions of objects, Gaia can assemble a clearer map than ever before, building up the picture from the inside.

And of course, any survey as large as Gaia will turn up unexpected results, often the most delicious kind in science.

SCANNING THE SKY


45°
Sun
Spin axis
Spacecraft rotates 4x each day
Spin axis precesses in 63 days
Telescope 1
Gaia
106.5°
Consecutive great circles
Telescope 2

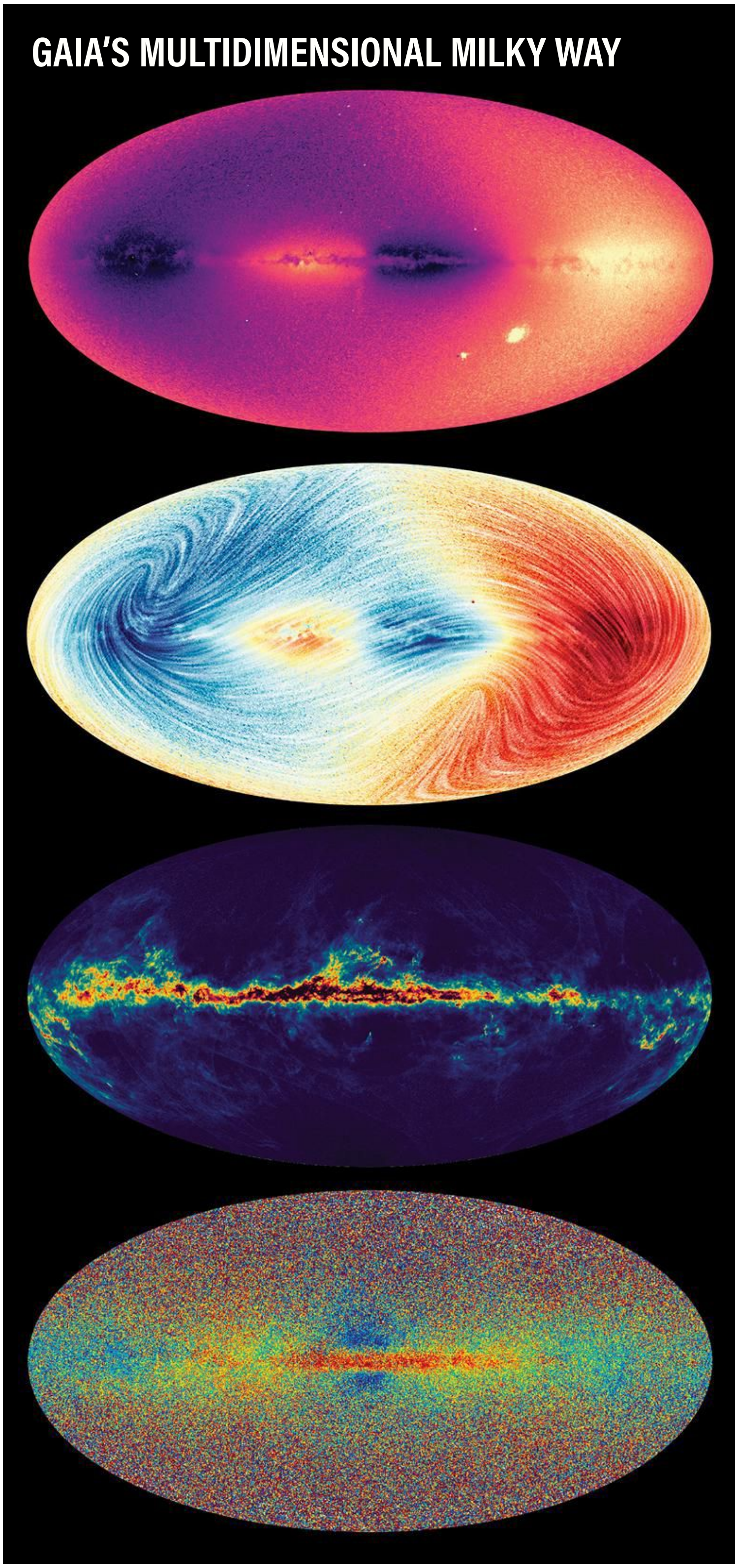
Gaia carried two identical telescopes, which pointed 106.5° apart on the sky and sent light to the craft's three instruments. These instruments recorded objects' positions, colors, and motions along the line of sight. The spacecraft spun slowly around its axis four times a day, scanning along a path called a great circle; as it did so, objects drifted from the field of view of one telescope to the other. The craft maintained an angle of 45° between the Sun and its spin axis to shade the telescopes while still allowing the solar panels to draw power. Additionally, the spacecraft's spin axis precessed, tracing out a complete circle on the sky every 63 days, allowing Gaia to see the entire sky over time. *ASTRONOMY*: ROEN KELLY, AFTER ESA

A picture of home

Of the 2 billion stars Gaia spied, the vast majority lay within the Milky Way. By measuring their positions and distances, astronomers can develop a more detailed and accurate map of our galaxy. And by charting stellar motions, astronomers can understand not just the big picture, but the smaller eddies, currents, and clusters of stars moving within the greater river of the Milky Way.

For instance, astronomers have known for years that the Milky Way's spiral isn't flat — it is warped, with a distinct kink. Gaia was able to not only better measure the shape of that warp, but also measure how it wobbles, or precesses, over time. Gaia data showed astronomers that the warp precesses relatively quickly, with a period of less than 700 million years. This suggests something dramatic like a collision with another galaxy caused it, as opposed to a bulge in our galaxy's dark matter halo, for instance, which would create a warp that precesses more slowly. The most obvious culprit is the Sagittarius dwarf spheroidal galaxy, which has probably collided with the Milky Way several times in the past as they slowly merge into one.

Closer to home, astronomers including João Alves at the University of Vienna in Austria have uncovered a



These four sky maps show off Gaia data released in June 2022 (Data Release 3). At top, a map of radial velocity shows the motion of stars toward or away from Earth, with darker colors moving toward us and brighter colors moving away from us. The map below it also shows motion toward (blue) and away (red) from Earth, this time combined with stars' proper motion — their projected motion across the sky — shown as the white lines. This combination of details allows astronomers to see how stars in different parts of the galaxy are moving in both speed and direction. The third oval down is Gaia's map of interstellar dust in our galaxy, showing not starlight but where that light is absorbed. Blacker regions along the center — the plane of the Milky Way — indicate more absorption (and more dust), while brighter colors show where there is less absorption (and less dust). The dark blue regions at the top and bottom of the oval map show where there is very little dust. At bottom is a chemical map of the Milky Way, revealing stars that contain higher concentrations of metals (redder colors); bluer colors are stars with fewer metals. Astronomers consider any elements heavier than hydrogen and helium to be metals. Older stars have fewer metals than more recent generations of suns.

ESA/GAIA/DPAC; CC BY-SA 3.0 IGO

9,000-light-year-long ribbon of gas undulating like a wave in the plane of the galaxy, called the Radcliffe Wave. Part of the structure lies only 500 light-years from Earth, in our local spiral arm, and was previously known to researchers and called the Gould Belt. Dotted along its length are stellar nurseries, hotbeds of star formation. Parts of the massive cloud had been seen before, but only Gaia data revealed the structure as a whole, which now stands as the largest known gas structure in the entire galaxy.

"The Gaia data were absolutely crucial to our discovery," Alves says. "This discovery significantly altered our understanding of the local Milky Way by replacing the idea of a Gould's Belt with a much larger, wavelike structure that influences star formation across a vast region of the Milky Way, and that might have affected Earth's climate about 14 million years ago" by introducing dust and radioactive particles into the solar system and Earth's atmosphere as it passed through the cloud.

In the stars

Gaia data have also allowed astronomers to become stellar archaeologists. By tracking stars' positions more precisely than ever before, astronomers can see how clusters of stars move together. This is a far more accurate way to discern clusters and groups of stars than by their positions, which can be misleading. After all, many stars that appear close together on the sky from Earth's perspective are actually separated by many light-years, lying vastly different distances away from us. Astronomers try to counter this by finding stars that appear not only close to one another but also share characteristics, but this too is an inexact science, as the results can be skewed by dust and measurement uncertainties.

Not only can Gaia judge distance more accurately than most previous surveys, it also tracks motion, and stars that move together are much harder to misinterpret.

Stars are born together in groups, so by mapping stars in smaller clusters, groups, and associations, astronomers can paint a picture of when different patches of stars came to be. Their time of birth isn't random, either. Many times, bursts of star formation are set off when galaxies collide or interact, mixing together dormant material.

Perhaps most illuminating, Gaia identified a group of some 30,000 stars that move together in a pattern different from the rest of the Milky Way's spiral flow, instead bobbing in and out of the center. Astronomers believe they are the remnant of a collision 10 billion years ago, when the young Milky Way and a galaxy now called Gaia Enceladus/Sausage merged. Another merger with a galaxy named Arjuna/Sequoia/I'itoi left behind globular clusters scattered through the Milky Way's halo that all move retrograde, against our galaxy's overall spin. Subsequent papers have uncovered even more mergers, painting a more complete history of our galaxy's tumultuous evolution.

Astronomers have also been able to trace some of these mergers' history from the location of specific clumps of stars. Among the discoveries are a series of ghostly filaments in the galaxy's outer disk, which astronomers suspect are the bones of ancient spiral arms, excited by tidal interactions when other galaxies passed close by the Milky Way in its early days.

Beyond the Milky Way

Gaia also spent time observing just outside the Milky Way, especially our close neighbor and familiar sight to observers in the Southern Hemisphere, the dwarf galaxy known as the Large Magellanic Cloud (LMC). According to Gaia data, the LMC is some 10 percent more massive than astronomers previously thought.

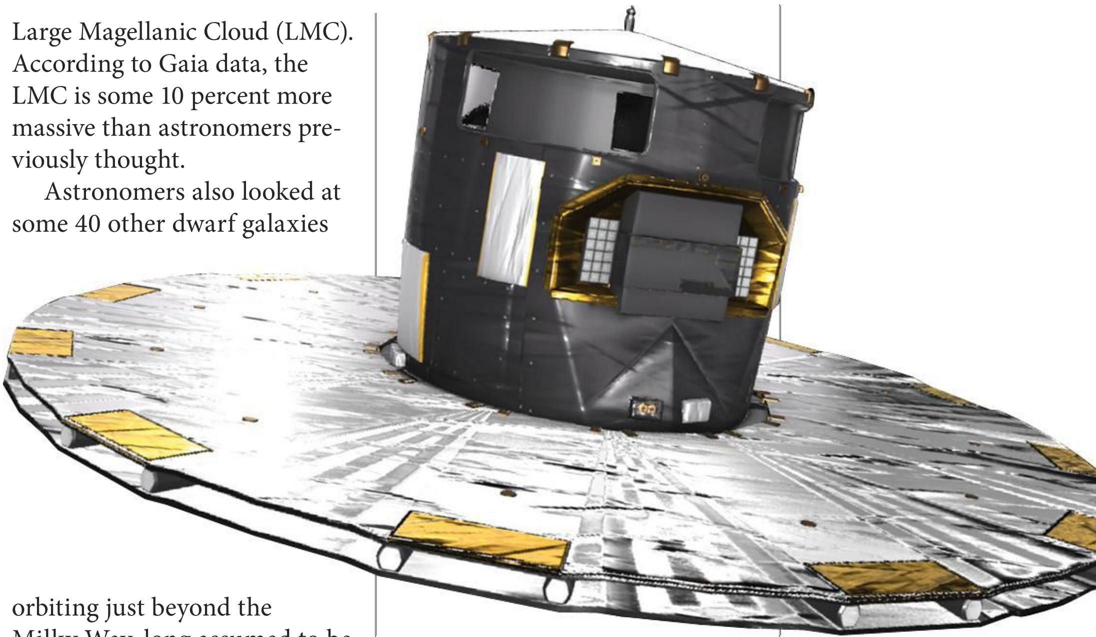
Astronomers also looked at some 40 other dwarf galaxies orbiting just beyond the Milky Way, long assumed to be satellites. Physics tells astronomers that in an encounter between the Milky Way and a dwarf galaxy, the smaller object would be ripped apart and incorporated into the larger Milky Way in just one or two passes. (Galaxy "collisions" are usually repeat events, as the two objects crash through and bounce back before fully merging.) So, astronomers had presumed, if these galaxies are orbiting as intact structures, then they must be more massive than they appear. This had been taken as an indication that dwarf galaxies, too, must harbor dark matter reservoirs.

But Gaia data indicate that rather than following settled orbits, most of those galaxies are in fact encountering the Milky Way for the first time, based on their surprisingly high speeds. A true satellite would move more slowly as interactions between it and the Milky Way sapped its energy. These are newcomers, still full of vim, vigor, and velocity.

Because they're not long-term satellites, however, they don't need to contain the dark matter previously believed to be holding them together. So, now astronomers must rethink yet again assumptions of how dark matter accumulates and where in the universe this spectral material can be found.

Turning its eyes to a different kind of quick-moving target, Gaia observations of hypervelocity stars within the Milky Way (stars zipping around with high radial velocities compared to background stars) have brought further revelations about the LMC. Astronomers think such stars get their speed from some sort of "kick," either from a companion star going supernova, or from veering too close to a black hole — particularly the Milky Way's central supermassive black hole.

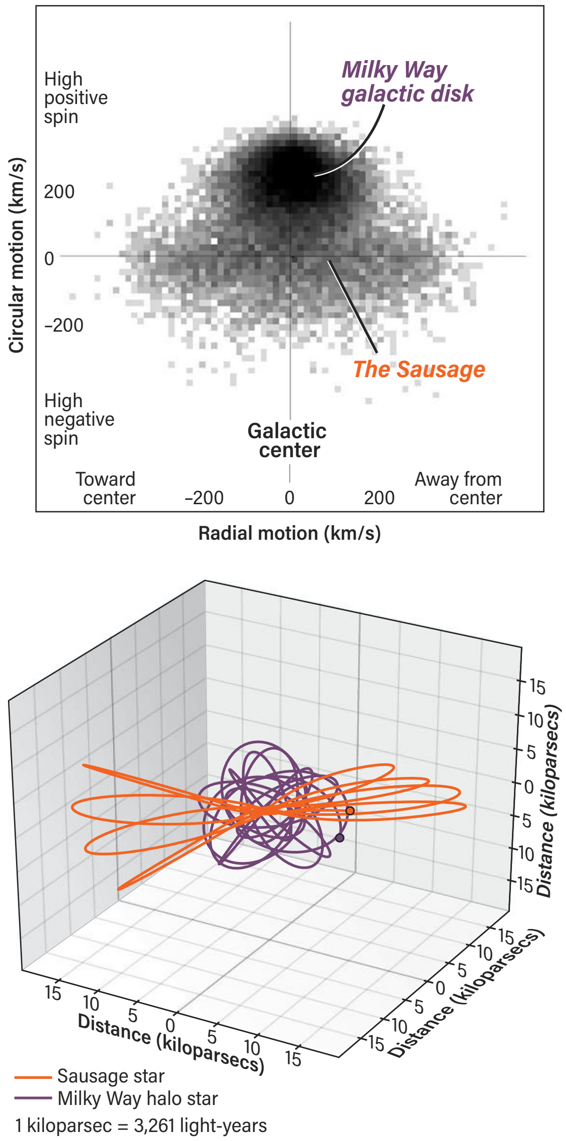
But when Jiwon Jesse Han of the Harvard-Smithsonian Center for Astrophysics traced back the path of a certain subset of these stars, he found they originated in the LMC. And given the stars' speed and history, the only plausible explanation for their particular distribution on the sky is that they were launched from the LMC by its own central supermassive black hole, making this dwarf just like its larger



↑ The Gaia spacecraft stretched nearly 33 feet (10 m) across with its solar panels and sunshield deployed. Its two telescopes surveyed the sky during the craft's 11-year mission, mapping some 2 billion stars and showing us our Milky Way Galaxy in unprecedented clarity.

ASTRONOMY: ROEN KELLY, AFTER ESA

HOW THE SAUSAGE WAS MADE



Looking at the way stars move allows astronomers to more easily see hidden groups of stars that are only revealed by their common motions through space. This is how researchers discovered the remnant of an ancient galactic collision. The plot at top includes the motions of 7 million stars measured by Gaia. On the vertical axis are stars' circular motions (i.e., the way they orbit the center of the galaxy), while the horizontal axis shows their radial motion (i.e., motion only toward or away from us). Stars in the Milky Way's disk have circular orbits with a speed of about 220 km/s (137 miles/second). But a separate set of stars (which appear to form a "sausagelike" shape on the plot, hence the Sausage moniker) have little of the expected circular motion around the galactic center, instead following very eccentric, needlelike orbits across the galaxy at some 400 km/s (250 miles/second). The plot at bottom shows the orbits of two different stars in 3D. Zero on each axis denotes the galactic center. The purple orbit follows a star in the galactic halo. The orange star is part of the Sausage group, with high radial motion toward and away from the galactic center, rather than the more circular motion of the halo star. *ASTRONOMY*: ROEN KELLY, AFTER V. BELOKUROV (CAMBRIDGE, UK AND CCA, NEW YORK, US) AND GAIA/ESA; *ASTRONOMY*: ROEN KELLY, AFTER A. DEASON (DURHAM, UK), SDSS AND GAIA/ESA

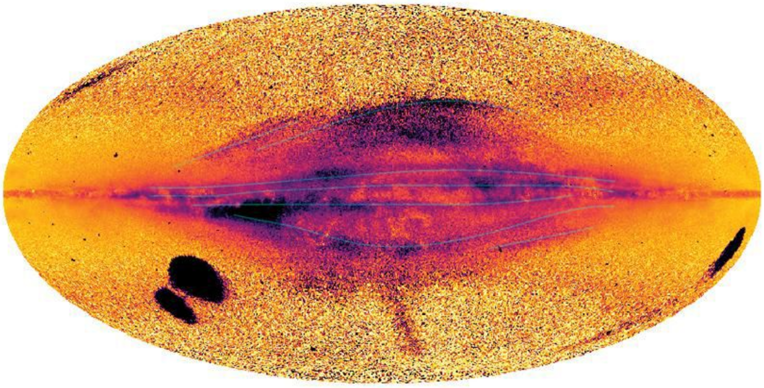
brethren galaxies. If confirmed, this would be a huge change in how we view our close neighbor, in which astronomers had previously found no solid evidence for a massive central black hole. That research was published in *The Astrophysical Journal* in March 2025.

And in February, the University of Amsterdam's Guðmundur Stefánsson found an exoplanet in the Gaia data, dubbed Gaia-4 b, weighing in at nearly 12 times the mass of Jupiter. It is the first exoplanet to be discovered with Gaia data alone — while Gaia has detected other exoplanets in the past, they have either been confirmations of previously detected planets, or required supporting data. In the same paper, Stefánsson's team also reports a brown dwarf, Gaia-5 b, about 21 times the mass of Jupiter.

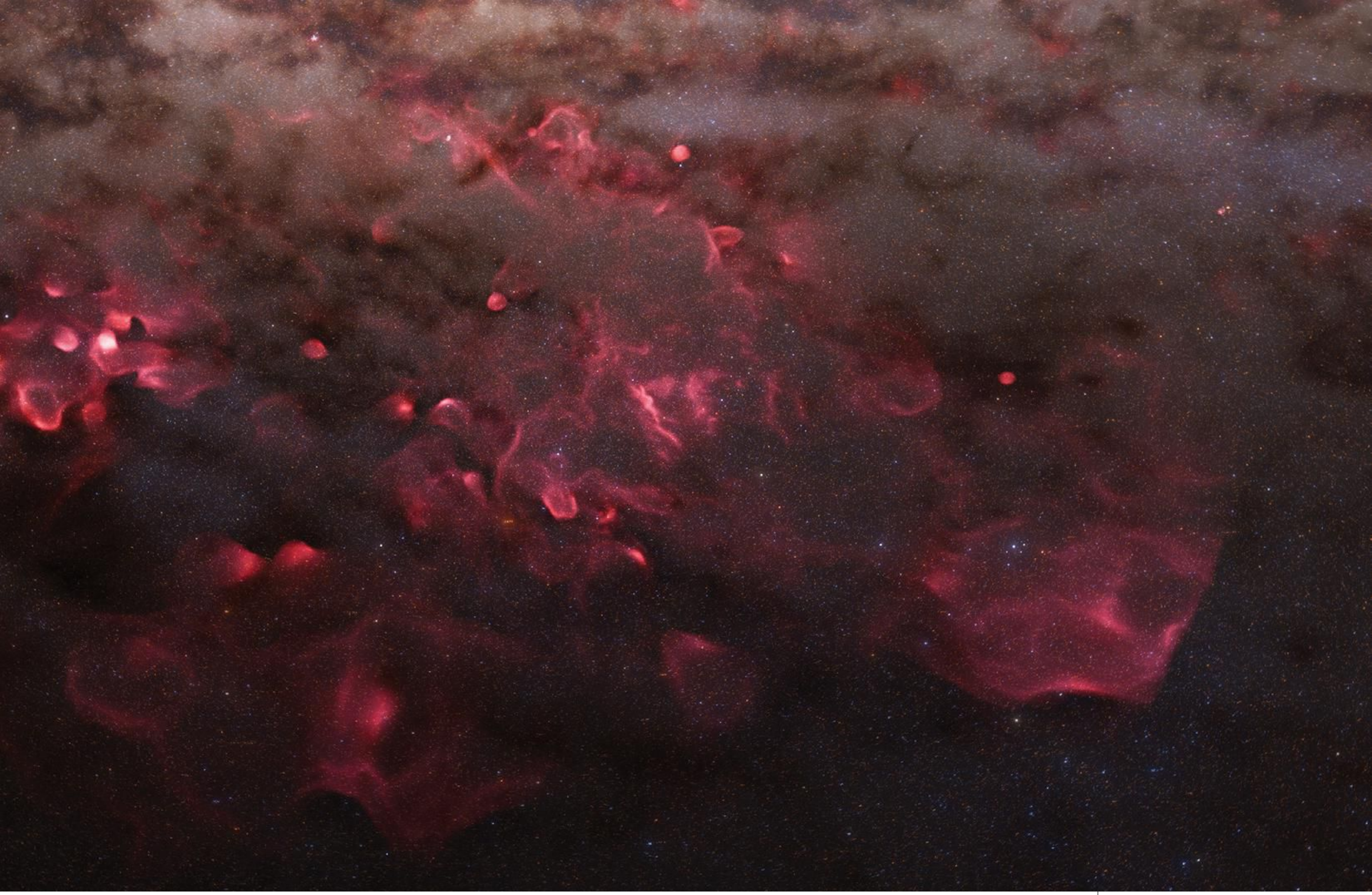
All these results are just the beginning. Johannes Sahlmann, a Gaia project scientist, says, "New results … are pouring in at a very high rate of more than five peer-reviewed scientific publications per calendar day. Those results cover virtually any field of astrophysical research, often with transformative impact."

Not done yet

The most recent data release, Data Release 3, was in 2022; two more are expected, in 2026 and around 2030. The release



This all-sky motion map created with Gaia data shows stars with high motions in black and purple, and those with little motion in yellow. The two dark regions at lower left are the Magellanic Clouds; the Sagittarius Dwarf Galaxy is the elongated black and purple curve at right. Traced out by blue lines are several filaments along which stars share similar motions. These structures may be the remnants of spiral arms excited into being along the galactic plane by past interactions between the Milky Way and other galaxies. LAPORTE ET AL. (CC BY 4.0)



in 2026 will cover five and a half years of data. In addition to the longer timespan, the Gaia team has improved instrument calibration and algorithms for processing the data, meaning the next batch of data will be even cleaner and more precise.

Sahlmann notes that this release will also include the individual measurements for 2 billion sources, instead of the more processed data of the earlier releases: "These will allow the data users to perform their own sophisticated analyses of these data, which so far has mostly been the realm of the Gaia consortium internal processing."

That 2026 data release will also include a large exoplanet candidate catalog, which has been a long time coming. When Gaia launched, astronomers predicted the telescope might find as many as 21,000 exoplanets during five years of observations. So far, the entire count from all of history stands at just over 6,000, so a jump this large would revolutionize the field.

That jump also makes sense — Gaia's steady eyes on the sky are similar to the way the Kepler telescope scanned for exoplanets, and Kepler transformed exoplanet science with a catalog of just 150,000 stars. But while Kepler watched for stars to dim as a planet passed across its surface, Gaia will see the tiny motion of the star as a planet tugs on it during its orbit.

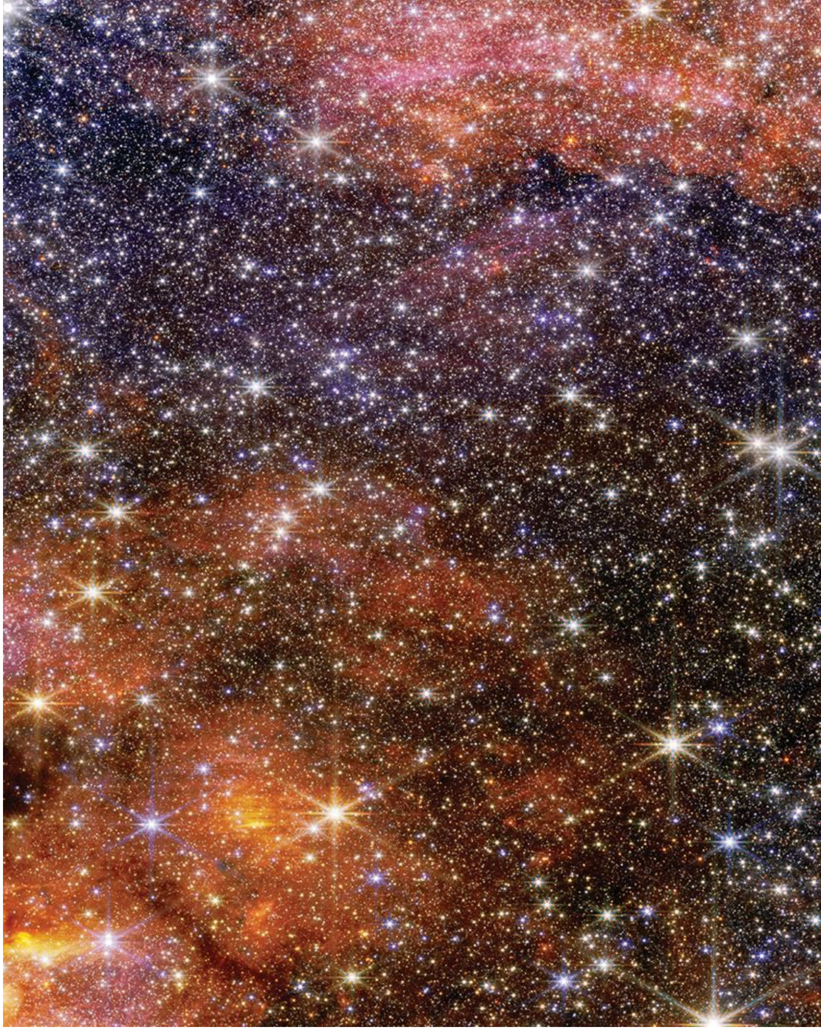
With the full 10 and a half years of observations, astronomers predict a haul of some 70,000 exoplanets, as well as exquisite precision when it comes to the overall mapping of stars in our galaxy. That data release won't happen until at least the end of the decade, around 2030 or later.

The long waits are due to the massive amounts of data — about a petabyte, or a million gigabytes, in the full dataset. All that data takes an immense amount of processing to untangle the minuscule shifts of stars on the sky from any noise from space or the telescope itself. It's a fine process, but it will be worth the wait.

"Gaia is now no longer acquiring new scientific data," Sahlmann says, "but in terms of the scientific exploration of the Gaia data, we remain only at the beginning. The most exciting discoveries still lie ahead of us and the Gaia mission catalogs have already become a new backbone for observational astronomy."

Korey Haynes *is an* Astronomy *contributing editor who enjoys teaching space science to students of all ages.*

↑ This still from an animation shows the three-dimensional distribution and structure of star-forming regions within 4,000 light-years of the Sun, colored in red. The view is from just above the plane of our local spiral arm, whose dust appears as dark streaks toward the top of the image. Mapping out such regions in 3D to study their structure is incredibly difficult, but Gaia's precise measurements have allowed researchers to begin charting these regions in such a way for the first time. These maps are based on information gathered from some 44 million stars. ESA/GAIA/DPAC, S. PAYNE-WARDENAAR, L. MCCALLUM ET AL (2025)



JWST explores the Milky Way's most prolific star-forming region.

BY RICHARD TALCOTT

DIVE INTO THE GALAXY'S

MASSIVE STARS have an outsized influence on their environment and the galaxies they call home. These behemoths have the highest surface temperatures of any normal stars, so they emit copious amounts of ultraviolet radiation that ionizes their surroundings. They also possess fierce stellar winds that help shape their gaseous environs. But these monster suns also burn through their nuclear fuels rapidly, so they don't live long and thus are exceedingly rare.

It's no wonder astronomers were eager to turn the penetrating eye of the James Webb Space Telescope (JWST) on nearby regions of massive star formation. And what better place to target than the Sagittarius B2 (Sgr B2) molecular cloud? This giant region of cold gas and dust is the biggest and most active star-forming region in our galaxy. It resides a few hundred light-years from the supermassive black hole, dubbed Sagittarius A*, that lies at the Milky Way's heart.

A Milky Way champion

At a distance of 27,000 light-years, Sgr B2 lies close enough to Earth that telescopes can provide a close-up view — only not at optical wavelengths. The dust that permeates the galaxy's disk effectively blocks most of the visible light from this region, but the longer infrared wavelengths JWST observes pass through relatively unscathed. Recent images reveal many of Sgr B2's massive young stars, the warm dust that surrounds them, and more than a dozen previously unseen regions of ionized hydrogen.

"Webb's powerful infrared instruments provide detail we've never been able to see before," said University of Florida astronomer Adam Ginsburg, principal investigator of the project, in a press release. "It will help us unravel mysteries of massive star formation and why Sagittarius B2 is so active."

How active is it? The so-called Central Molecular Zone (CMZ) stretches more than 1,500 light-years across our galaxy's core and holds approximately 80 percent of the Milky Way's dense gas. Yet it produces only about 10 percent of the galaxy's stars — less than one-tenth of what theory would suggest. Sgr B2 is the exception, creating nearly half of the CMZ's stars in its 150-light-year-wide volume. It churns out stars at a rate of about 4 solar masses per century, which translates into eight to 10 stars. (No, our galaxy is not a prolific star producer.)

The new images offer a few clues as to why Sgr B2 stands out. First, the clouds

CENTER

ABOVE: At near-infrared wavelengths, JWST shows the massive star-forming region Sagittarius B2 packed with young stars and dense clouds of gas and dust giving birth to future stellar generations. ALL IMAGES: NASA, ESA, CSA, STSCI, A. GINSBURG (UNIVERSITY OF FLORIDA), N. BUDAIEV (UNIVERSITY OF FLORIDA), T. YOO (UNIVERSITY OF FLORIDA)

BELOW: At mid-infrared wavelengths, JWST reveals glowing clouds of warm dust. Many fewer stars appear in this image because fainter ones emit little long-wavelength radiation.

that give birth to the most massive stars seem especially dense, which makes them more resistant to disruption. Second, a sharp boundary on the cloud's eastern edge (visible at the top left of the images) hints that a recent event, perhaps the passage of a shockwave from a nearby supernova, triggered the recent bout of star formation.

Tip of the iceberg

The researchers say their results suggest that Sgr B2 may have only just begun creating stars. If so, the galaxy's most active star-forming region has expanded its lead over second place. As lead author Nazar Budaiev of the University of Florida said, "For everything new Webb shows us, there are new mysteries to explore."

Astronomers value every insight JWST delivers into massive star formation not only for what it reveals about the Milky Way, but also for what it says about distant galaxies. Studies of Sgr B2 should help scientists better understand the conditions in galaxies at earlier cosmic times, some 3.5 billion years after the Big Bang, when the rate of star formation peaked.

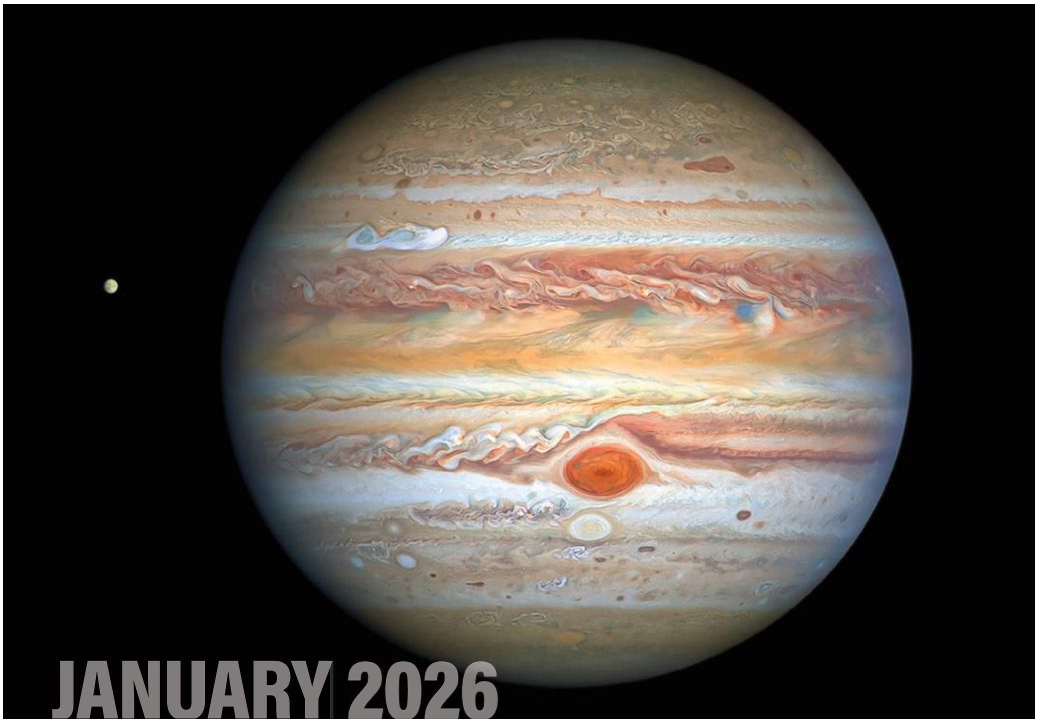
Contributing Editor **Richard Talcott** *remembered the life and times of astronaut Jim Lovell in the December issue.*

SKY THIS MONTH

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.

BY MARTIN RATCLIFFE AND ALISTER LING



Jupiter reaches opposition this month, looking its best, while the motions of its moons are fascinating to watch. This 2020 Hubble image shows Jupiter and its icy moon Europa. NASA, ESA, A. SIMON (GODDARD SPACE FLIGHT CENTER), AND M. H. WONG (UNIVERSITY OF CALIFORNIA, BERKELEY) AND THE OPAL TEAM

JANUARY 2026

Jupiter at opposition

Saturn is on display in the early-evening sky this month along with Uranus and Neptune, both within reach of binoculars. Jupiter dominates the night, reaching opposition on the 10th. The gas giant is the prime target for the month; the long winter nights offer lots of time to enjoy the view. Mercury continues its year-end showing through the New Year, visible in the morning sky for a brief time.

Saturn and **Neptune** remain in the same binocular field of view all month. Saturn is easy to spot, shining at magnitude 1.0. It crosses from Aquarius into Pisces on the 15th. Neptune stands 3.5° northeast of Saturn on the 1st, and Saturn's path brings it to within 1.7° of Neptune by the 31st. Neptune shines at magnitude 7.8, requiring optical aid to see it. Catch these two planets early in the evening, as they set before midnight.

Neptune lies 2.8 billion miles from Earth and its disk spans only 2". With Saturn in your field of view, move northeast to find the dim, bluish-hued disk. Its nonstellar appearance will give it away.

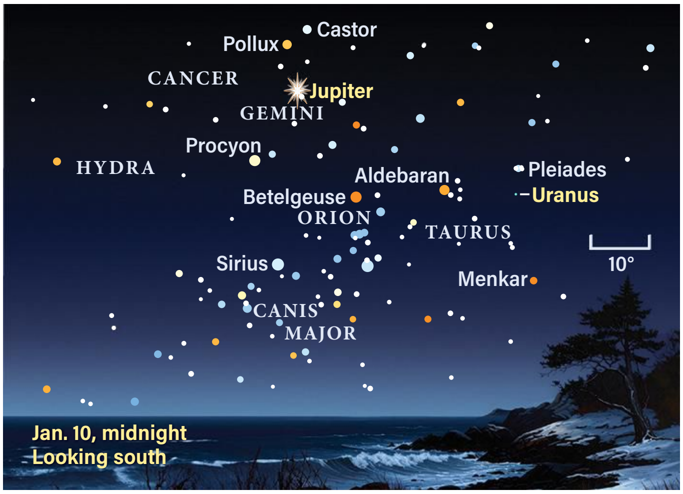
Saturn lies much closer at 924 million miles from Earth, and its disk spans 17". The rings show a very shallow tilt, beginning January at 1° and increasing to 2.2° by the 31st. The thin rings will almost disappear in small telescopes. The entire disk of the planet is visible, with some subtle features in its atmosphere evident to patient observers who wait for steady moments of good seeing.

Eighth-magnitude Titan is the largest moon. It wanders back and forth every week during its 16-day orbit. You'll find the moon near Saturn on Jan. 1, 9, 17, and 25.

Tethys, Dione, and Rhea, all shining at 10th magnitude, orbit Saturn interior to Titan. They undergo close conjunctions at regular intervals, often near the rings, which are fascinating to view. Enceladus shines at 12th magnitude and is often hard to see due to the nearby brilliance of the rings, but it's easier now. It remains within about 37" of Saturn, or about 15" beyond the edge of the rings at the extremes of its orbit.

Iapetus reaches inferior conjunction with Saturn Jan. 14, when the 11th-magnitude moon stands 1.2' due north of the planet. Iapetus moves west of Saturn during January and slowly increases in brightness as its lighter hemisphere turns earthward. As it approaches its

Mighty giant



Jupiter shines brightly in Gemini as it reaches opposition this month. It's also a great time to view Uranus near the Pleiades in Taurus, though you'll need binoculars or a telescope. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

JUPITER reaches opposition Jan. 10 and is visible all night.

early February western elongation, the moon brightens to 10th magnitude and reaches a point nearly 8' west of Saturn by month's end.

It's a great time to view **Uranus**, nicely located in Taurus and high in the sky after sunset. Uranus lies south of the Pleiades star cluster (M45) and is easy to spot in binoculars, shining at magnitude 5.7. Look south of M45 for a pair of 6th-magnitude stars, 13 and 14 Tauri. Uranus wanders west of the pair and begins the month 22" southwest of 13 Tau, the westernmost of the two suns. By Jan. 31, Uranus stands 47" southwest of this star. The ice giant is visible most of the night, setting around 2 A.M. local time on the 31st. A gibbous Moon is in the vicinity on the 26th and 27th.

Through a telescope, Uranus reveals a pale greenish disk spanning 4". Observers with experience in planetary high-speed video capture might want the challenge of recording Uranus while it is high in the sky soon after sunset.

Jupiter, the solar system's largest planet, reaches opposition Jan. 10. It's up all night, shining at its maximum brilliance of magnitude –2.7. Jupiter is perfectly placed for Northern Hemisphere observers, located in Gemini the Twins and climbing above 60° in altitude before midnight.

— Continued on page 34

RISING MOON | Hoofing it across the ditch

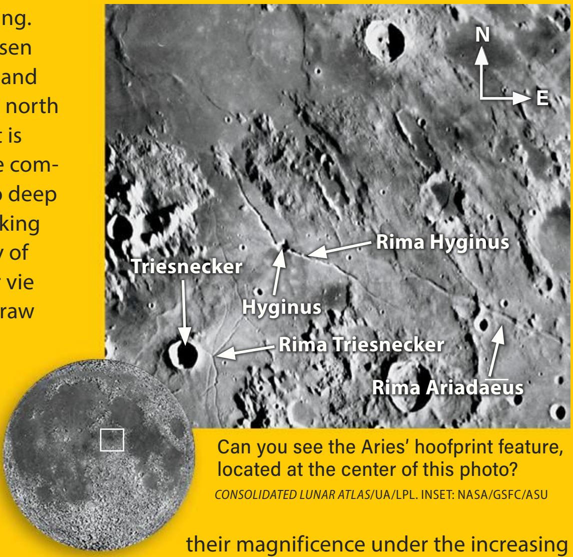
ARIES THE RAM certainly did not step on the Moon, but it's fun to imagine the large hoofprint on the lunar surface could be his doing. On the evening of the 25th, the Sun has risen over the fascinating Hyginus, Triesnecker, and Ariadaeus rille complexes. In this area just north of the equator, what catches the eye most is a delightful hoofprint-shaped feature. The combination of brightly lit mountains and two deep channels of extra-dark lava create this striking play of light and shade. The dazzling array of craters farther south along the terminator vie for attention, but the cracks and shapes draw us back.

It's easy to understand why it is not labeled on the lunar maps — physically it is a just jumble of mountains left over from the giant Imbrium impact, with a channel on either side. Furthermore, lunar scientists focused on the fascinating Rima Hyginus with good reason, as it is almost surely volcanic in origin. Hyginus itself is a huge collapse pit, the biggest in a chain of smaller pits that sculpt the edges of a long-ago lava channel. It too stands out nicely because one wall is brightly sunlit while the other remains in shadow.

In the course of 24 hours, Aries' hoofprint and the Hyginus rille become mere echoes of their magnificence under the increasing glare of the Sun. To see the region with reverse lighting, check it out late on the evenings of the 8th and 9th for the longest shadows.

For south pole Mount Clementine fans, zoom in from the 1st to the 5th to watch this fantastic area in 3D relief, and again as the calendar flips to February.

Hyginus, Triesnecker, Ariadaeus rilles

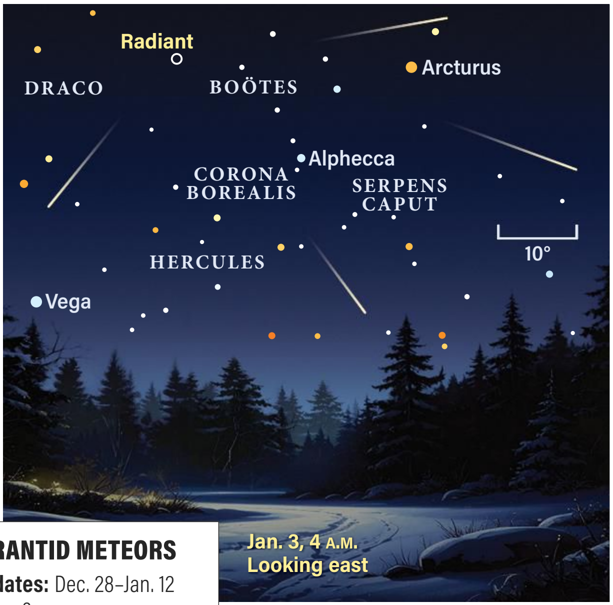


Can you see the Aries' hoofprint feature, located at the center of this photo?

CONSOLIDATED LUNAR ATLAS/UA/LPL. INSET: NASA/GSFC/ASU

METEOR WATCH | Only the brightest

Quadrantid meteor shower



Despite the Full Moon, step outside the morning of Jan. 3 to look for brighter Quadrantid fireballs.

QUADRANTID METEORS

Active dates: Dec. 28–Jan. 12
Peak: Jan. 3
Moon at peak: Full
Maximum rate at peak: 80 meteors/hour

THE QUADRANTID METEOR SHOWER is a regular on the calendar, active between Dec. 28 and Jan. 12. The parent object is asteroid 2003 EH$_1$, likely the leftover core of a once-active comet. This year the peak coincides with a Full Moon, strongly depleting the number of visible meteors to only the brighter ones. The meteor stream is known to be narrow; the International Meteor Organization predicts the peak of the shower around 4 P.M. EST Jan. 3, with maximum activity for a few hours on either side of this time. This timing benefits observers in Asia.

In the U.S., the radiant rises shortly before midnight local time and by 4 A.M. it's nearly 45° high. Rates will be reduced to well under a dozen per hour at the peak, and on the early morning of Jan. 3, U.S. observers will see fewer than this number. However, the Quadrantids are known to produce fireballs, which makes it an exciting shower to watch.

STAR DOME

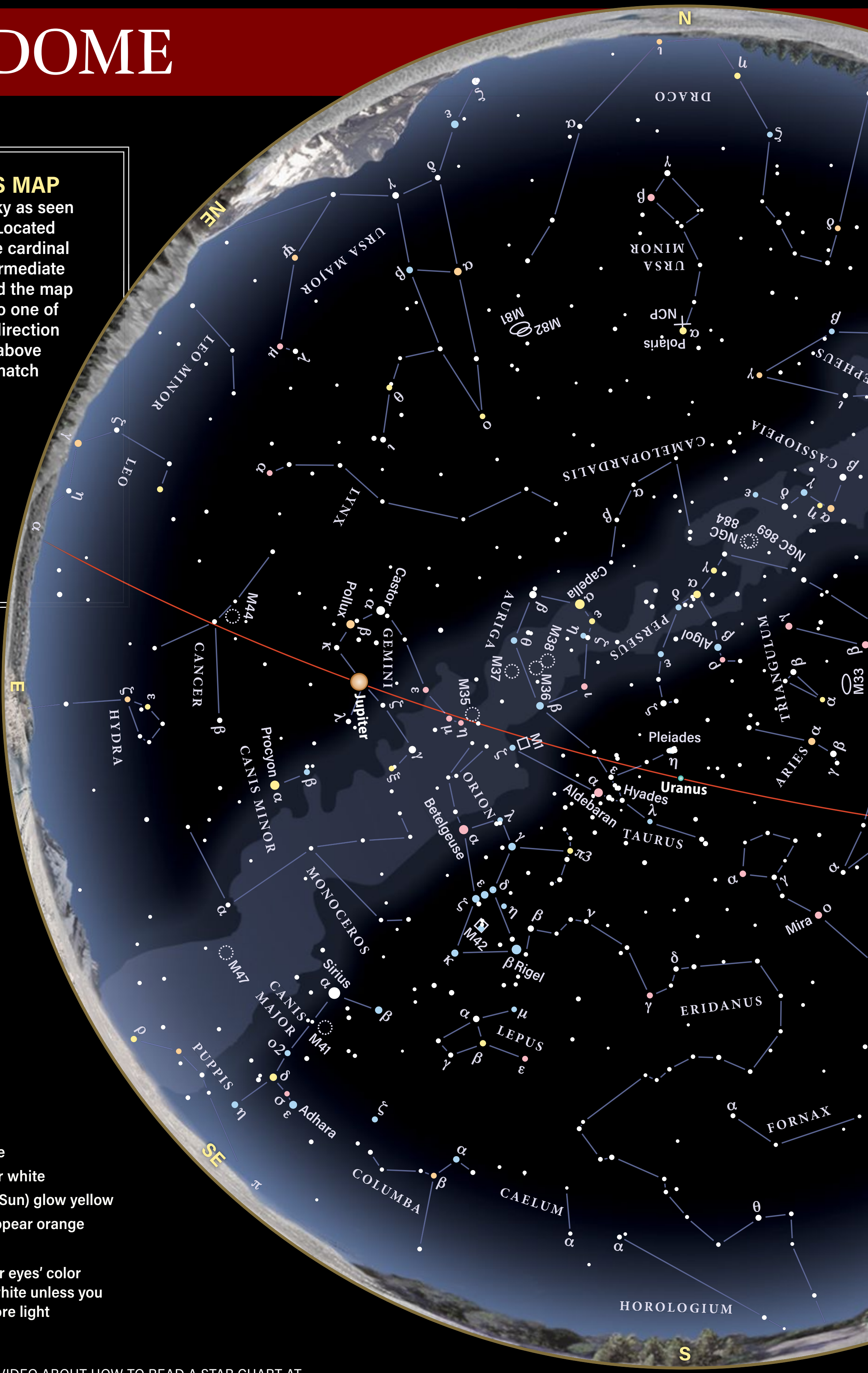
HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. January 1
8 P.M. January 15
7 P.M. January 31

Planets are shown at midmonth


N
DRACO
URSA MINOR
NCP
Polaris
M81
M82
URSA MAJOR
NE
LEO MINOR
LEO
LYNX
CAMELOPARDALIS
CASSIOPEIA
CEPHEUS
NGC 884
NGC 869
Capella
AURIGA
PERSEUS
Algol
TRIANGULUM
M33
Castor
Pollux
GEMINI
M44
CANCER
E
HYDRA
Jupiter
M35
M36
M37
M38
M1
Pleiades
Uranus
ARIES
Hyades
Aldebaran
TAURUS
Procyon
CANIS MINOR
ORION
Betelgeuse
MONOCEROS
M42
Rigel
Mira
ERIDANUS
M47
Sirius
CANIS MAJOR
M41
LEPUS
PUPPIS
Adhara
SE
COLUMBA
CAELUM
FORNAX
HOROLOGIUM
S

MAP SYMBOLS

- ◌ Open cluster
- ⊕ Globular cluster
- □ Diffuse nebula
- ⌖ Planetary nebula
- ⬭ Galaxy

STAR MAGNITUDES

● Sirius

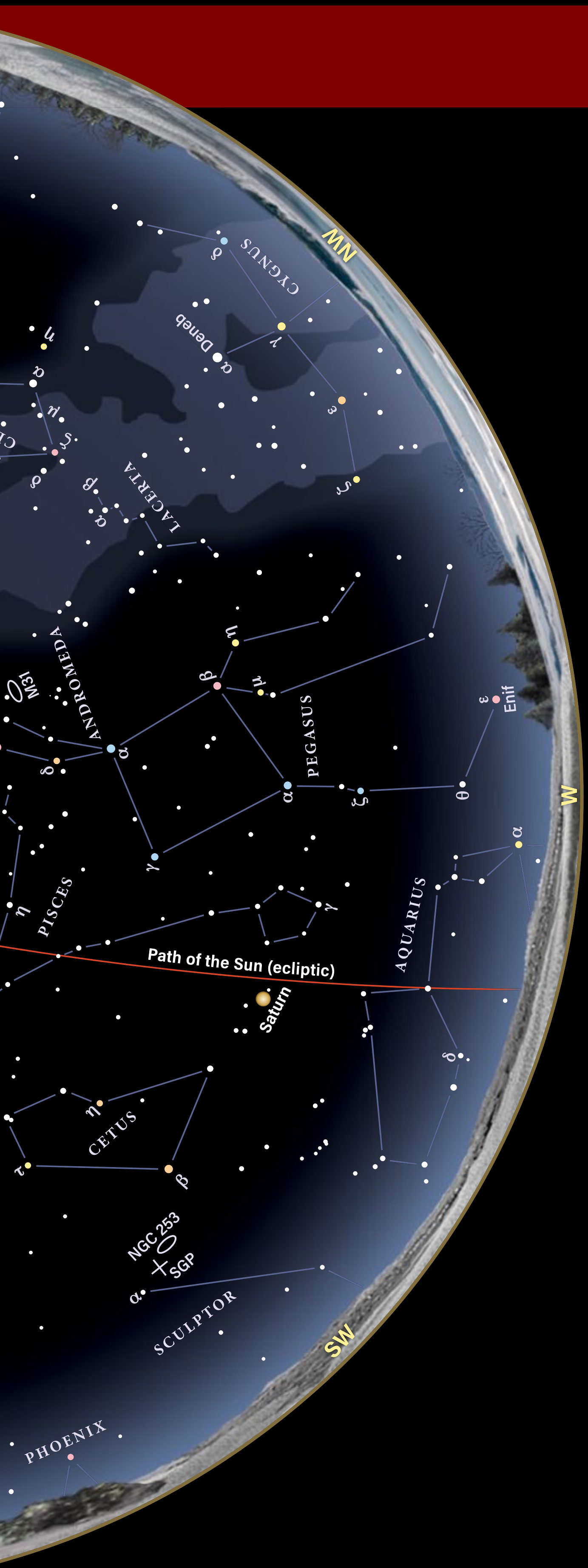
●	0.0	•	3.0
●	1.0	•	4.0
•	2.0	·	5.0

STAR COLORS

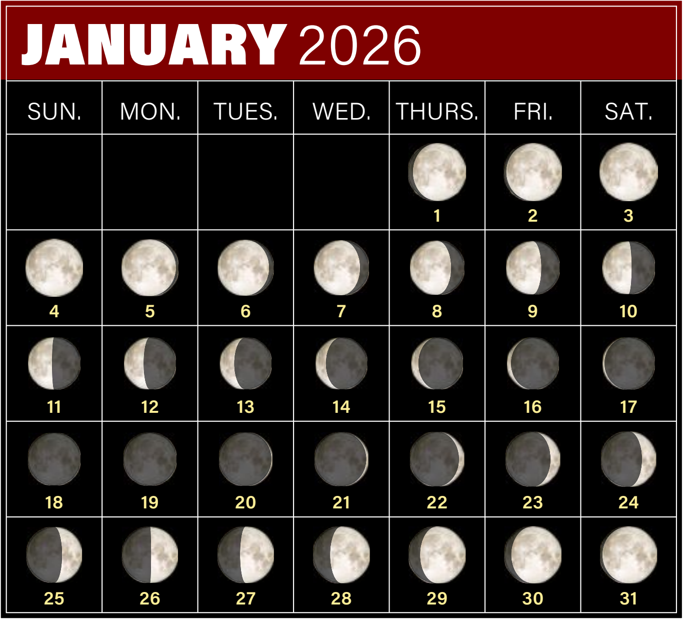
A star's color depends on its surface temperature.

- ■ The hottest stars shine blue
- ■ Slightly cooler stars appear white
- ■ Intermediate stars (like the Sun) glow yellow
- ■ Lower-temperature stars appear orange
- ■ The coolest stars glow red
- ■ Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



JANUARY 2026



SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 The Moon is at perigee (223,910 miles from Earth), 4:44 P.M. EST

2 Asteroid Harmonia is at opposition, 10 A.M. EST

3 Full Moon occurs at 5:03 A.M. EST

Earth is at perihelion (91.4 million miles from the Sun), noon EST

The Moon passes 4° north of Jupiter, 5 P.M. EST

Quadrantid meteor shower peaks

6 Venus is in superior conjunction, noon EST

The Moon passes 0.5° north of Regulus, noon EST

9 Mars is in conjunction with the Sun, 7 A.M. EST

10 Jupiter is at opposition, 4 A.M. EST

Last Quarter Moon occurs at 10:48 A.M. EST

13 The Moon is at apogee (251,928 miles from Earth), 3:47 P.M. EST

14 The Moon passes 0.6° south of Antares, 3 P.M. EST

18 New Moon occurs at 2:52 P.M. EST

21 Mercury is in superior conjunction, 11 A.M. EST

23 Pluto is in conjunction with the Sun, 5 A.M. EST

The Moon passes 4° north of Saturn, 8 A.M. EST

The Moon passes 4° north of Neptune, 11 A.M. EST

Asteroid Nysa is at opposition, noon EST

25 First Quarter Moon occurs at 11:47 P.M. EST

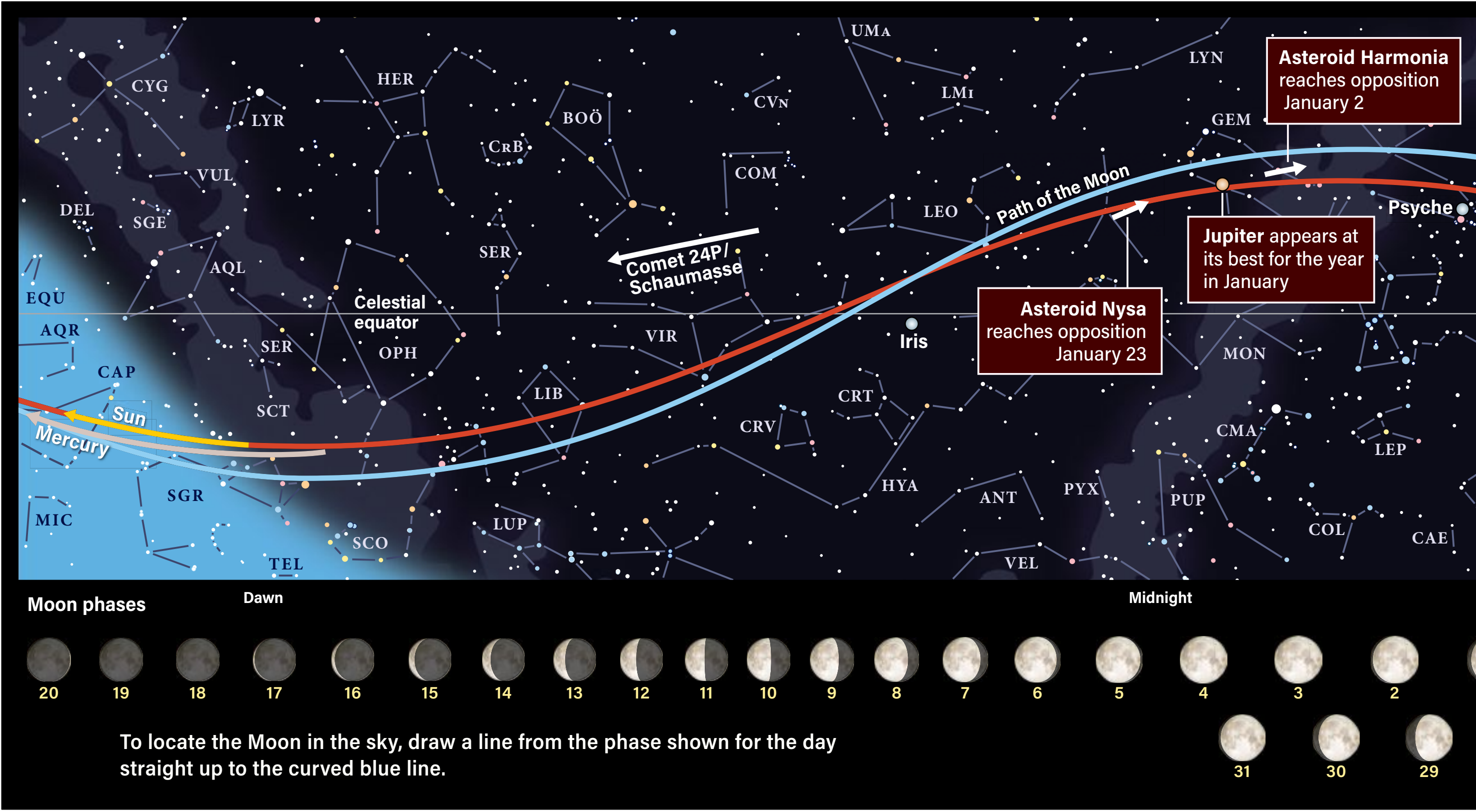
27 The Moon passes 5° north of Uranus, 2 P.M. EST

28 Asteroid Vesta is in conjunction with the Sun, 3 P.M. EST

29 The Moon is at perigee (227,341 miles from Earth), 4:46 P.M. EST

30 The Moon passes 4° north of Jupiter, 9 P.M. EST

PATHS OF THE PLANETS


UMa
LYN
CYG
HER
LYR
BOÖ
CVn
LMi
GEM
CrB
VUL
COM
DEL
SGE
LEO
Path of the Moon
Psyche
SER
Comet 24P/ Schaumasse
AQL
EQU
Celestial equator
AQR
OPH
SER
VIR
Iris
MON
CAP
Sun
LIB
CRT
CMA
LEP
Mercury
SCT
CRV
HYA
ANT
PYX
PUP
SGR
MIC
LUP
COL
CAE
SCO
TEL
VEL
Moon phases
Dawn
Midnight
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
31
30
29

Asteroid Harmonia reaches opposition January 2

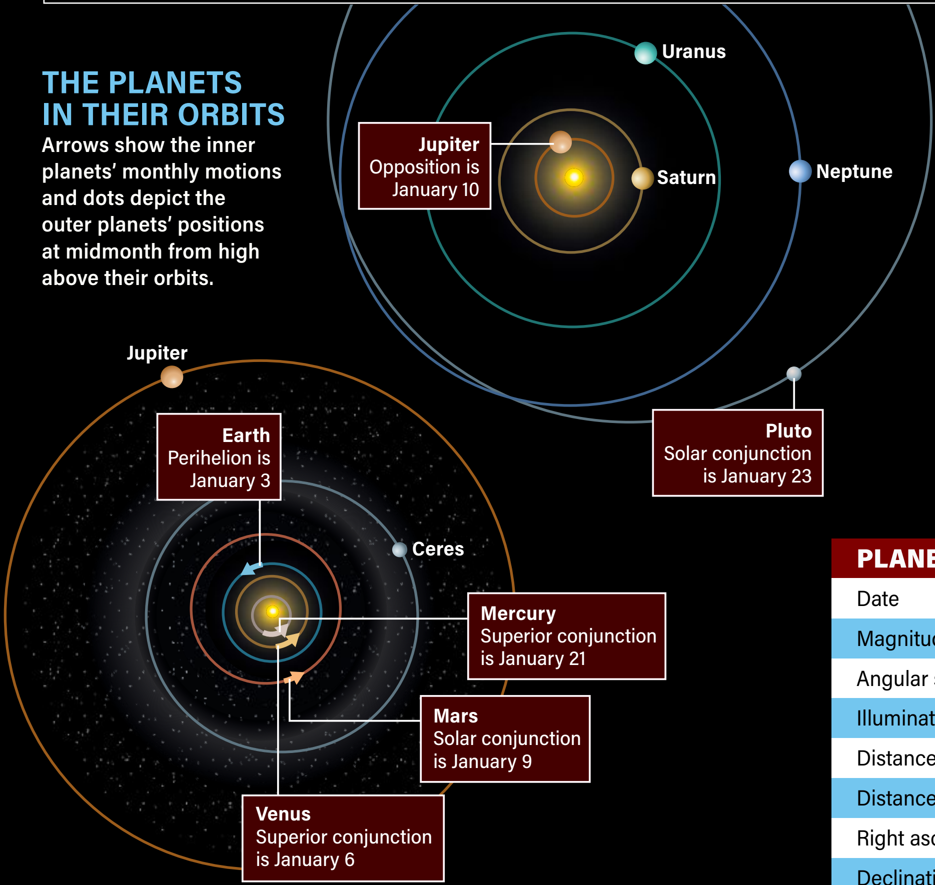
Jupiter appears at its best for the year in January

Asteroid Nysa reaches opposition January 23

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

THE PLANETS IN THEIR ORBITS

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.


Uranus
Saturn
Neptune
Jupiter
Ceres

Jupiter Opposition is January 10

Pluto Solar conjunction is January 23

Earth Perihelion is January 3

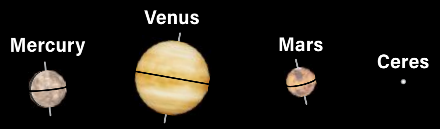
Mercury Superior conjunction is January 21

Mars Solar conjunction is January 9

Venus Superior conjunction is January 6

THE PLANETS IN THE SKY

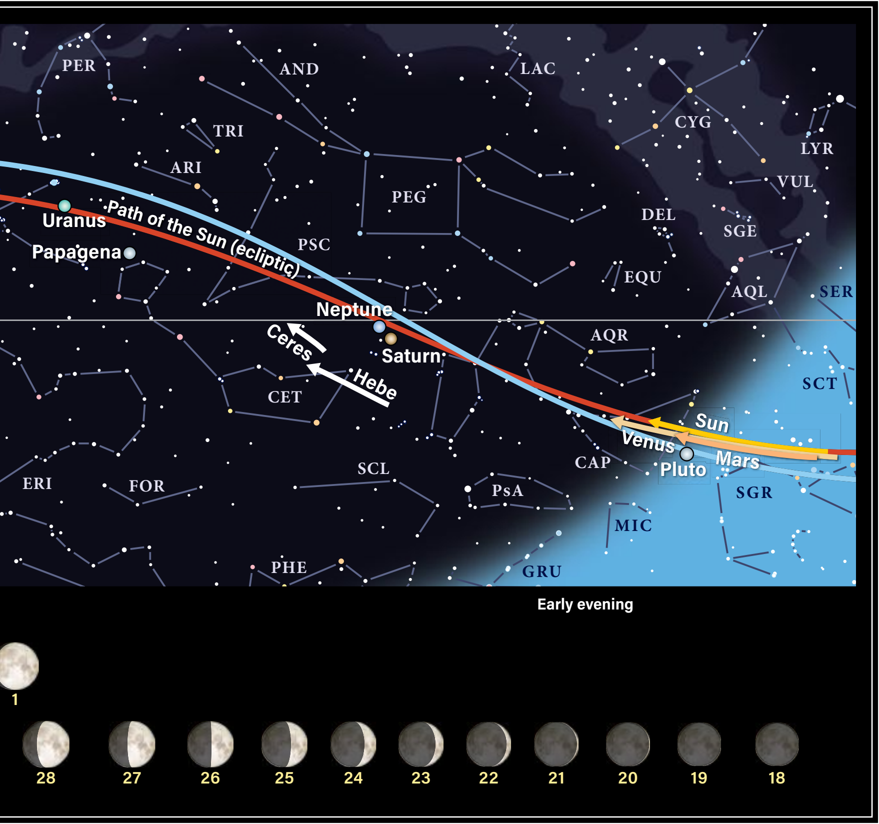
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.


Mercury
Venus
Mars
Ceres

PLANETS	MERCURY	VENUS
Date	Jan. 1	Jan. 15
Magnitude	–0.6	–3.9
Angular size	4.9"	9.8"
Illumination	95%	100%
Distance (AU) from Earth	1.378	1.710
Distance (AU) from Sun	0.463	0.728
Right ascension (2000.0)	17h52.5m	19h54.7m
Declination (2000.0)	–24°00'	–21°49'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

JANUARY 2026

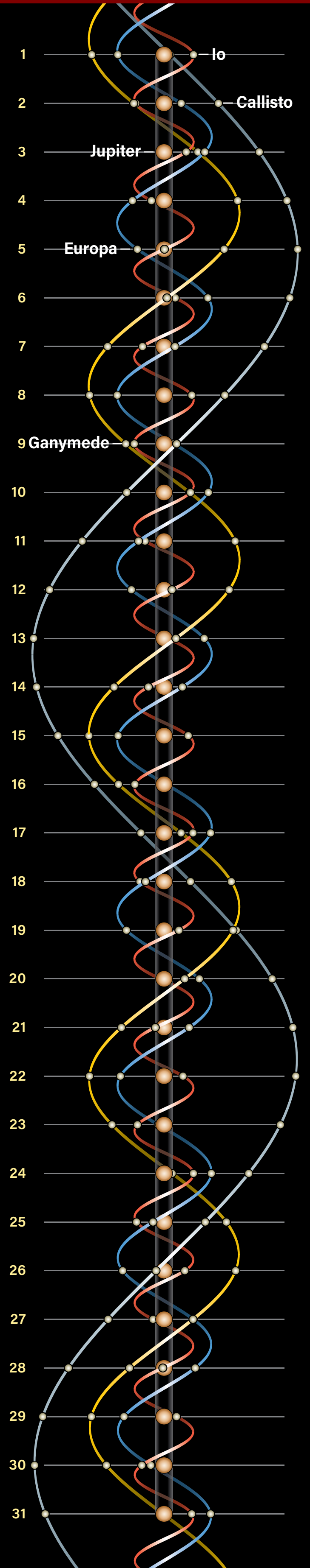

PER
AND
LAC
TRI
CYG
LYR
ARI
VUL
PEG
DEL
SGE
Uranus
Path of the Sun (ecliptic)
PSC
Papagena
EQU
AQL
SER
Neptune
Ceres
Saturn
AQR
Hebe
SCT
CET
Sun
Venus
Pluto
Mars
CAP
SCL
ERI
FOR
PsA
SGR
MIC
PHE
GRU
1
28
27
26
25
24
23
22
21
20
19
18

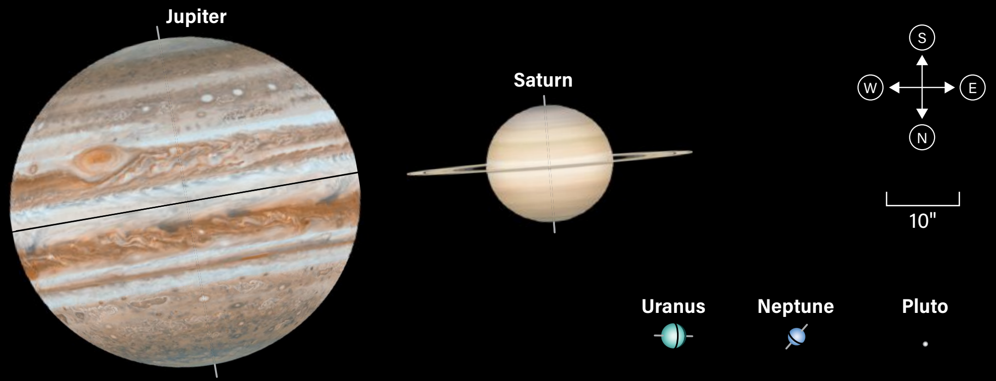
Early evening

Callisto
Europa
Io
Ganymede

JUPITER'S MOONS

Dots display positions of Galilean satellites at 10 P.M. EST on the date shown. South is at the top to match the view through a telescope.



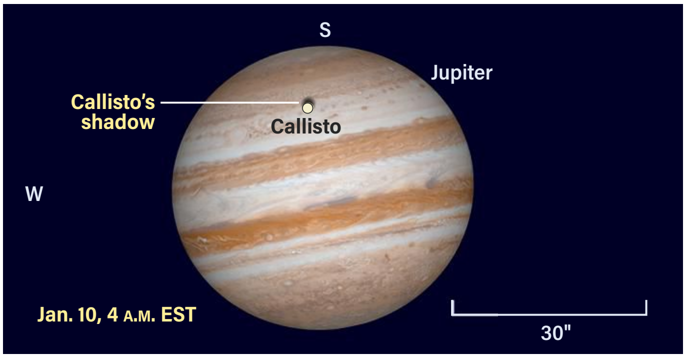

Jupiter
Saturn
S
W
E
N
10"
Uranus
Neptune
Pluto

MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Jan. 15	Jan. 15	Jan. 15	Jan. 15	Jan. 15	Jan. 15	Jan. 15
1.1	9.0	–2.7	1.0	5.7	7.8	15.2
3.9"	0.5"	46.5"	16.7"	3.7"	2.3"	0.1"
100%	97%	100%	100%	100%	100%	100%
2.398	2.958	4.237	9.931	18.937	30.288	36.402
1.415	2.878	5.217	9.514	19.488	29.884	35.431
19h40.5m	0h49.4m	7h22.9m	23h51.7m	3h40.1m	23h59.8m	20h24.1m
–22°25'	–3°23'	22°31'	–3°19'	19°21'	–1°28'	–23°13'

SKY THIS MONTH

— *Continued from page 29*

Spot the shadow



The day Jupiter reaches opposition, Callisto nearly blends with its shadow as they transit. Can you spot the shadow, just peeking out from Callisto's southern edge?

Jupiter sports a 46"-wide disk, making atmospheric features visible in most telescopes. Two dark equatorial belts jump out immediately, and more patient viewers are rewarded with numerous shaded features — huge storms that are generated by turbulence caused as the equatorial and polar regions of the planet rotate at different speeds. The equatorial regions complete one rotation in 9 hours 50 minutes, and higher latitudes take five to six minutes longer, generating shear where they meet.

The Great Red Spot dominates the southern edge of the South Equatorial Belt. If it's not visible early in the evening, try again a few hours later. With such long nights, you're guaranteed a view of it every night, although some appearances are in the early morning.

Jupiter's four largest moons — Io, Europa, Ganymede, and Callisto — dance around the planet with periods ranging from two to 17 days. You can watch them appear from and disappear behind the disk or cast shadows onto the cloud tops as they transit in front of the planet.

With Jupiter near opposition, there are some fascinating shadow transits early this month. Before opposition, the shadow always precedes its moon across the jovian disk. After opposition, the moon transits first, followed obediently by its shadow. This month we're lucky to see Callisto transit the day of opposition, which means the moon overlaps its own shadow.

First, though, Callisto kicks off the month as it reappears from behind Jupiter Jan. 1 at about 9:02 P.M. EST. Its reappearance takes about 10 minutes. When do you first spot the moon at Jupiter's northeastern limb?

Shadow transits get underway Jan. 5, as Io's shadow takes a notch out of Jupiter's eastern limb starting around 8:50 P.M. EST. Io reaches the limb six minutes later, at 8:56 P.M. EST. An hour later they're central on the disk, and leave beginning around 11:05 P.M. EST as the shadow departs, followed by Io six minutes later.

Two events occur close together on Jan. 6. Ganymede orbits Jupiter farther out than Io, so its shadow leads the moon by 20 minutes. Make sure you're watching the planet at 8:30 P.M. EST as Ganymede approaches the eastern limb. Io reappears from behind Jupiter beginning at 8:32 P.M. EST, and takes three minutes to fully emerge.

As Io moves away from the limb, Ganymede creeps closer. Starting at 8:59 P.M. EST,

WHEN TO VIEW THE PLANETS

EVENING SKY
Jupiter (east)
Saturn (southwest)
Uranus (east)
Neptune (southwest)

MIDNIGHT
Jupiter (south)
Uranus (west)

MORNING SKY
Mercury (southeast)
Jupiter (west)

COMET SEARCH | Night crawler

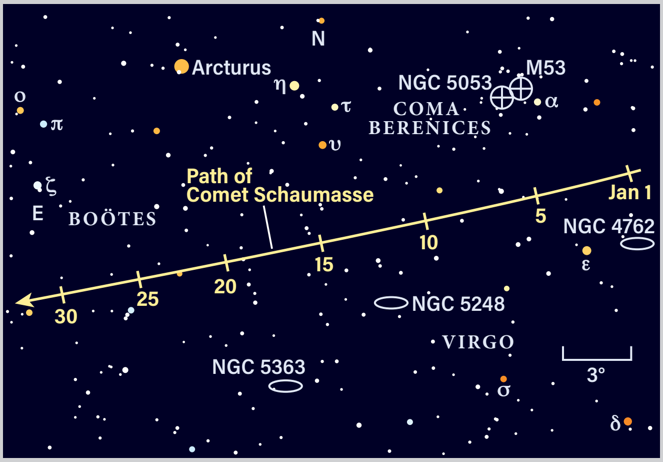
DEDICATED COMETOPHILES will be content with a modest telescopic target from a dark site. Comet 24P/Schaumasse should be glowing green from diatomic carbon emission throughout this perihelion passage, now 1.2 astronomical units (AU) from the Sun. (One AU is the average Earth-Sun distance.) This will make a nice contrast to the white glow of background galaxies as it exits the Virgo Cluster region. Patience and planning are required — you'll need enough energy to be alert at 2 A.M.

Despite several returns since its discovery in 1911, Schaumasse's peak brightness is forecast in a wide range from 8th to 12th magnitude. Part of the uncertainty is that it has been known to have strong enough jet activity to modify its orbit. Take a close look at medium to high power along the east flank, where that jet should make a sharp leading edge with a soft, fading shallow fan to the west and north.

Once Schaumasse has faded in a couple of months, its awkward 8.2-year period gives us poor return geometries until 2059, when it gets as close to Earth as 0.3 AU and shines near 6th magnitude.

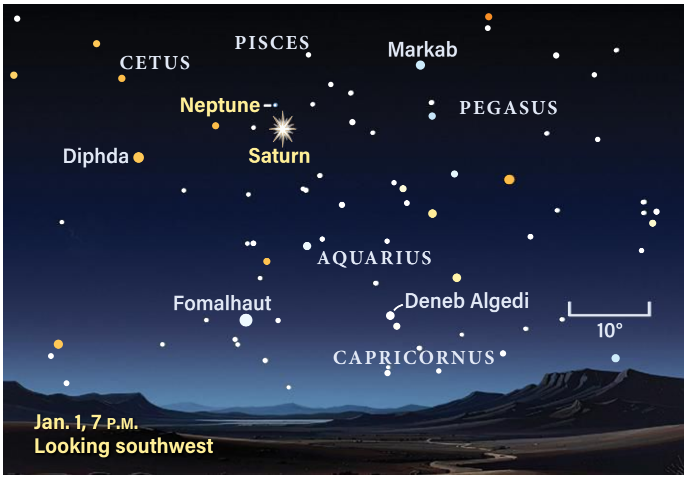
South of the equator, observers are treated to the bright binocular comet C/2024 E1 (Wierzchoś) rising into the deepening evening twilight after midmonth. At perihelion on the 20th, it may surge beyond the expected 5th magnitude.

Comet 24P/Schaumasse



Comet Schaumasse leaves the galaxy-rich regions of Virgo and spends its time south of Arcturus later this month.

Sticking together



Jan. 1, 7 p.m.
Looking southwest

Saturn continues to point the way to Neptune all month; note that Neptune requires optical aid to view. They are best seen in early evening.

Ganymede's shadow appears on Jupiter's disk. By 9:09 p.m. EST the shadow is fully visible, and nine minutes later, Ganymede itself begins ingress. Watch over the next three hours as the pair transits, ending with the shadow leaving by about 12:24 a.m. EST (now the 7th in the Eastern time zone) and Ganymede moving clear of the disk by 12:45 a.m. EST.

Jan. 7 sees Europa in action, crossing the disk with its shadow. The shadow transit begins at 11:35 p.m. EST, followed by Europa seven minutes later. By midnight CST (1 a.m. EST on the 8th) the moon and shadow are central on the disk, with Europa more of a challenge to see against the bright background. The shadow transit ends by 2:30 a.m. EST, with Europa clear of the disk seven minutes later.

There's a special treat Jan. 9/10 as Jupiter reaches opposition. Callisto transits Jupiter, overlapping with its own shadow because the illuminating source, the Sun, is directly behind us as we view the planet. The transit begins minutes before 2 a.m. EST on Jan. 10 (11 p.m. PST on the 9th). By 2:10 a.m. EST the transit is fully underway, and Callisto reaches the center of the disk by about 4 a.m. EST. Do you see any evidence of the shadow? Callisto may exhibit a darker southern edge, which is due to the shadow. The transit ends shortly after 6 a.m. EST.

On Jan. 12 we're past opposition so when Io transits, this time its shadow trails the moon. Io begins its transit around 10:39 p.m. EST and its shadow follows about four minutes later. By 10:50 p.m. EST both are clearly visible on the disk. They reach midway an hour later.

Ganymede transits again Jan. 13/14, this time also with the moon leading. Ganymede reaches the disk at 12:34 a.m. EST (the 14th in EST only), followed by the shadow at 12:58 a.m. EST. The pair takes nearly three hours to cross Jupiter. Ganymede transits again on the morning of Jan. 21, starting at 3:51 a.m. EST. Its shadow now trails the moon by more than an hour, and appears at 4:58 a.m. EST.

This sequence shows off the changing illumination as Jupiter passes through opposition. Later this month, the moon-shadow separation further increases.

Mercury may be visible briefly the morning of the New Year, glowing at magnitude –0.6 and 2° high in the southeastern sky about 30 minutes before sunrise. With a clear horizon, you might spot it. The sky brightens quickly so the observing window is only a few minutes. After this, Mercury quickly heads toward its superior conjunction with the Sun on the 21st.

Venus reaches superior conjunction with the Sun Jan. 6 and **Mars** reaches conjunction with the Sun on the 9th. Neither of these planets is visible this month.

***Martin Ratcliffe** is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City. **Alister Ling**, who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

LOCATING ASTEROIDS

Psyching out the Bull

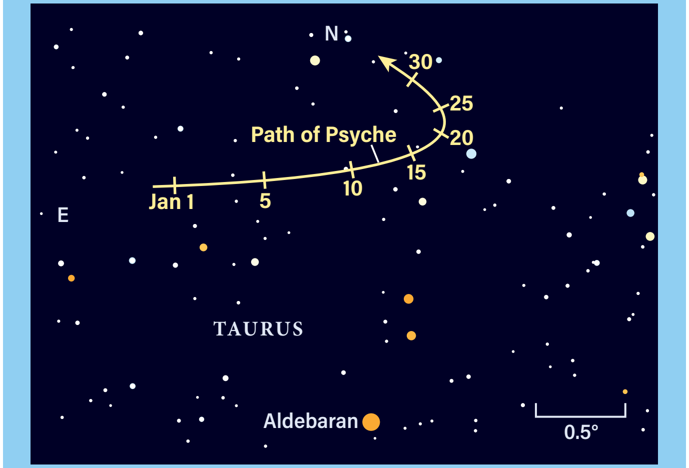
FIRST-MAGNITUDE ALDEBARAN commands the eastern sky, a snap to get to and perhaps the last of the stars in your align process. Curling just above Taurus' ruddy eye is the 16th asteroid to be discovered, 16 Psyche, yours to see with a 3-inch scope from the suburbs at medium power.

With just two field sketches you can track Psyche's movement for the entire month. Early in the month, locate the zigzag of 8th- to 9th-magnitude stars just northeast of Aldebaran and place them at the bottom of one circle. Next, drop a few fainter 10th-magnitude dots half a field north — one of these will be the target. Return to see which has moved.

Later in the month, look due north of Aldebaran and follow a gentle curve of stars that hooks toward the northeast. Those last three are your anchor. On the 10th, the 173-mile-wide, potato-shaped metallic space mountain is the slightly fainter component of a temporary "double star" with the end of the hook.

Just three short years from now, we'll get close-up views from an orbiting NASA spacecraft. Psyche is going to be very different from Ceres or Vesta — exciting!

Keeping an eye on things



The strange, metallic asteroid Psyche arcs above the Bull's eye, Aldebaran, this month.

GET DAILY UPDATES ON YOUR NIGHT SKY AT
www.Astronomy.com/skythisweek.

Have astronomers uncovered a new type of supernova?

A team led by the Harvard-Smithsonian Center for Astrophysics and MIT as part of the Young Supernova Experiment has captured the explosive interaction between a black hole and a massive nearby star (blue), as depicted in this artist's conception.

MELISSA WEISS/CFA

A strange blast, flagged by AI, provides the strongest evidence yet of a star being detonated by its black hole companion.

BY BROOKS MENDENHALL

Using an artificial intelligence algorithm, astronomers have discovered a new type of supernova that likely results from the merging of a dying star and its black hole companion.

In July 2023, the Zwicky Transient Facility detected supernova SN 2023zkd, located 730 million light-years from Earth. Six months later, in January 2024, an AI algorithm known as the Lightcurve Anomaly Identification and Similarity Search (LAISS) flagged the explosion as anomalous.

The detection and subsequent analysis were conducted by a team led by the Harvard-Smithsonian Center for Astrophysics (CfA) and MIT as part of the Young Supernova Experiment (YSE). The alert from LAISS triggered immediate and widespread follow-up observations, which proved essential in unraveling the supernova's highly unusual nature.

Those observations revealed two behaviors that depart from a typical supernova. First, the star had been brightening for at least four years before its final detonation. Second, the explosion didn't fade away as expected, but dramatically rebrightened about 240 days later. Both can be explained, the team says, if the star's death was triggered by merging with a black hole companion.

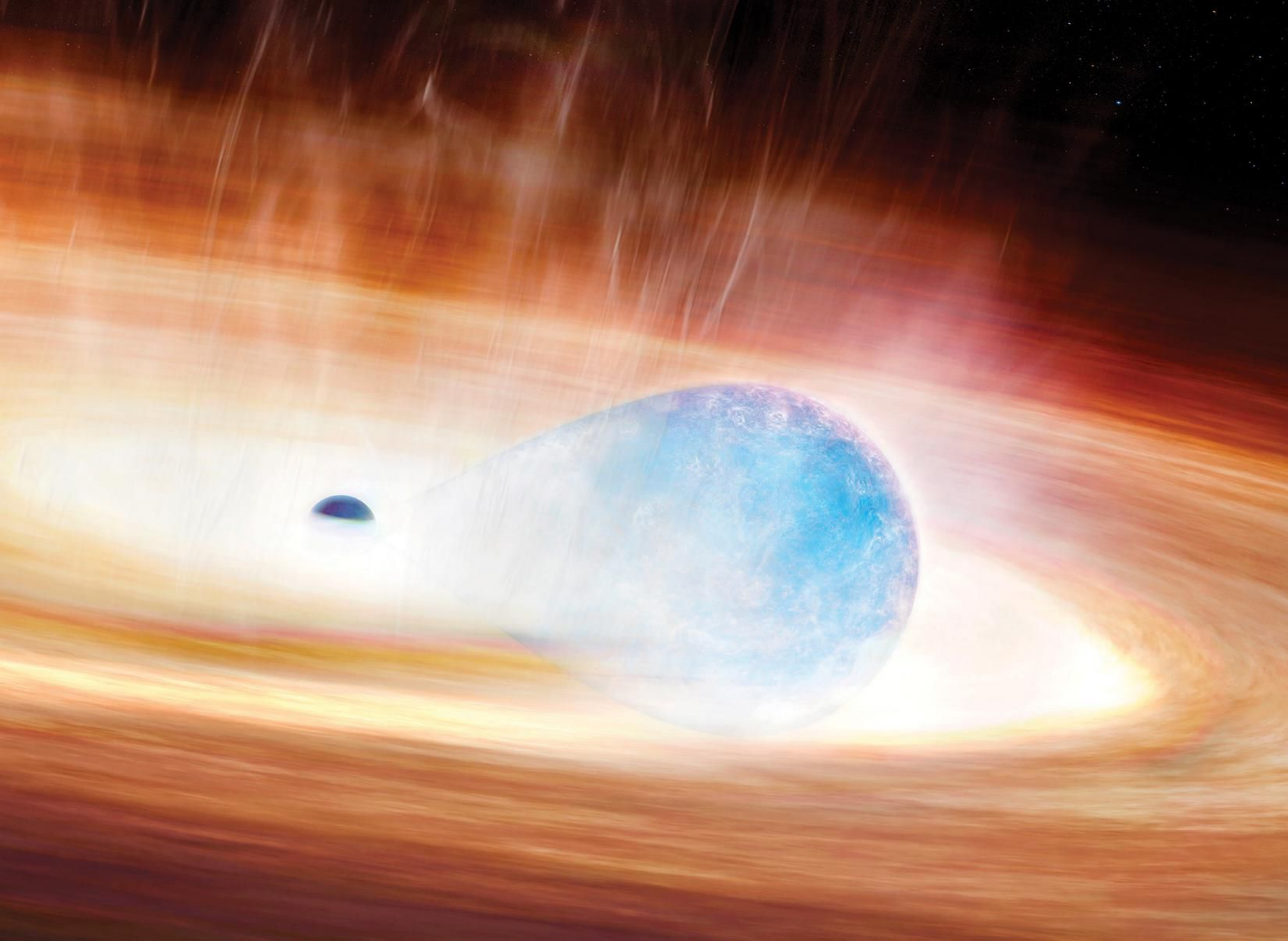
The team's findings were published Aug. 13 in *The Astrophysical Journal.* "We think this might be part of a whole class of hidden explosions that AI will help us discover," said V. Ashley Villar, an astronomer at Harvard University and a co-author on the study, in a CfA press release.

A cosmic anomaly

A star spends its life in a delicate balancing act, with the outward pressure from nuclear fusion in its core pushing against the inward crush of gravity. As a star runs out of hydrogen — its main fuel for fusion — it begins fusing heavier and heavier elements, until the chain reaches iron. Fusing iron consumes energy rather than releasing it, so the star's engine abruptly shuts off. This shatters the star's equilibrium: With nothing to halt its collapse, gravity wins. If the star is massive enough, the core implodes and the star's outer layers rebound off the newly formed, ultradense object, launching a huge shock wave. This is known as a standard type II supernova.

SN 2023zkd belongs to a special subclass called type IIn. The *n* signifies the explosion happens inside a dense cloud of gas the star previously shed. The supernova's shock wave slamming into this material creates a complex light show.

But even for this chaotic class of events, SN 2023zkd stood out as strange: By analyzing archival data, the team



found that before it exploded, it had been brightening for four years. The team calls this activity the "precursor" period, and splits it into two phases: Precursor A, a long initial period of steady brightening; and Precursor B, a final, accelerated ramp-up.

Uncovering this highly unusual behavior was an "'aha' moment," says the study's lead author Alex Gagliano, an astronomer and postdoctoral research fellow with the NSF-funded Institute for AI and Fundamental Interactions (IAIFI). The "years-long ramp-up to the explosion … is a very clear prediction of a scenario involving a star and a black hole."

The team concluded that the two objects were in a "really, really tight binary," spiraling in toward each other. This process was "very messy," Gagliano says, and formed a complex system with multiple structures.

First, as the black hole yanked material off the star, some of that material swirled toward the black hole, forming an accretion disk wrapped around it. As this material heated up prior to disappearing into the black hole, it generated the Precursor A emission. At the same time, some of the material shed from the star formed a larger disk outside both the black hole and the star, creating a dense so-called circumbinary disk enveloping the entire system.

Meanwhile, the furious interplay between the star and black hole also ejected material along the system's poles, forming clouds of gas above and below its orbital plane. The origin of this polar material — whether it is from the star directly or from the circumbinary disk — is still an open question.

A helpful, if imperfect, analogy for the system's resulting structure is the Homunculus Nebula surrounding the star Eta (η) Carinae, which also features a pinched equatorial disk and large polar lobes of ejected gas.

Then, as the star and black hole chaotically spiraled toward each other more tightly in the year before the explosion, their interaction created Precursor B, the final, bright ramp-up emission.

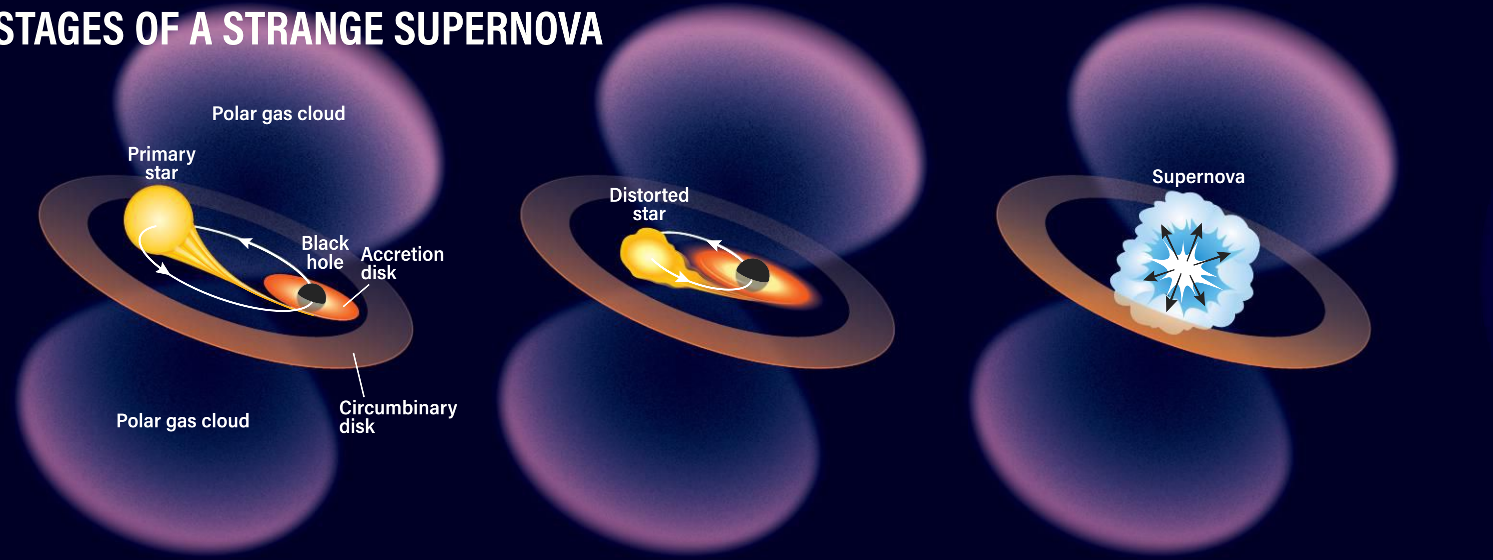
A double-peaked explosion

The star's unusual preexplosion activity was only half of the mystery. After a supernova detonates, its brightness typically climbs to a single, brilliant peak before beginning a steady fade. And SN 2023zkd followed this script at first.

But after several months of fading as expected, it rebrightened, reaching a second, nearly as brilliant peak about 240 days after the first. This extremely rare occurrence was the second major clue that this event was unlike a standard stellar explosion.

Using computer models, the team

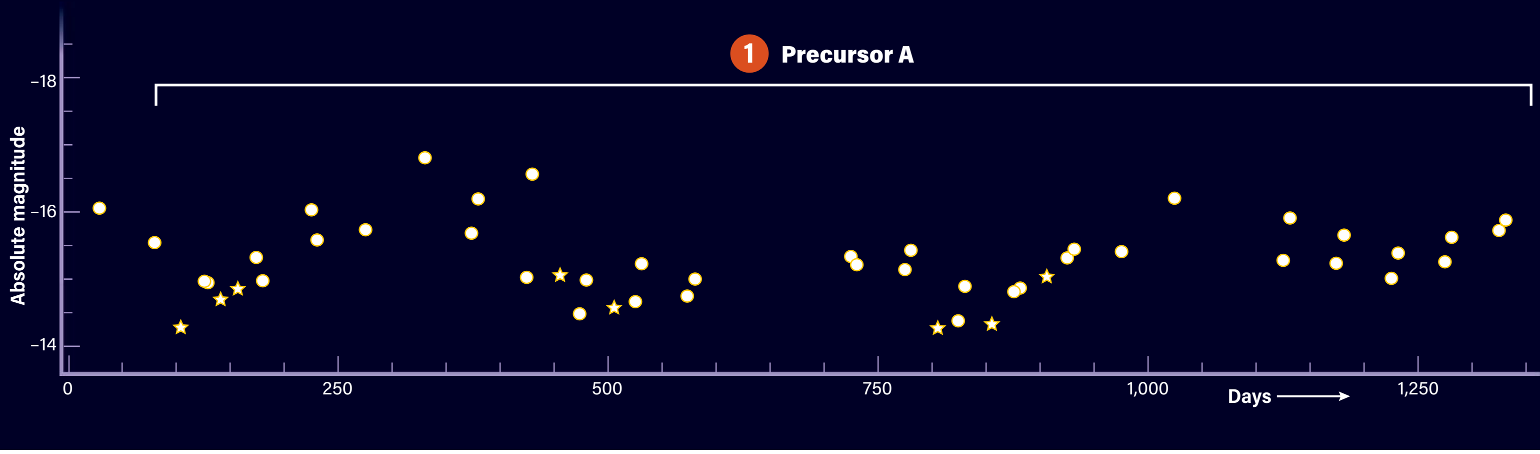
STAGES OF A STRANGE SUPERNOVA



① The system takes shape
Years before the explosion, a dying star and its black hole companion orbit in a tight spiral. The black hole’s immense gravity siphons material from the star, forming a glowing-hot accretion disk. This process, along with messy outbursts ejecting polar gas clouds and a dense equatorial disk, causes the system to brighten steadily, creating the multiyear signal known as Precursor A.

② A star stretched to its limit
In the final year before the supernova, the interaction becomes a runaway process. The star, now distorted and stretched, sheds its outer layers at an accelerated rate, leading to Precursor B. The two objects spiral chaotically and violently toward their final merger.

③ A new kind of supernova
The gravitational stress of the merger triggers the supernova. The blast wave rips outward from the center of the chaotic system.



found that the first peak came from the shock wave hitting the diffuse polar clouds, and the second, more sustained peak was caused by it slamming into the dense circumbinary disk.

The sequence is counterintuitive: Why would the collision with the circumbinary disk — which lies inside the polar clouds — create the *second* peak? The answer is an observational effect driven by the structures’ differing densities, says Gagliano. When the supernova’s blast wave moved through the system, the low-density polar clouds were swept up rapidly. As the shock wave moved through these clouds and excited their atoms, it created a huge, expanding photosphere — the visible surface layer from which light can escape — inside of which “everything is so hot that it’s opaque,” Gagliano says.

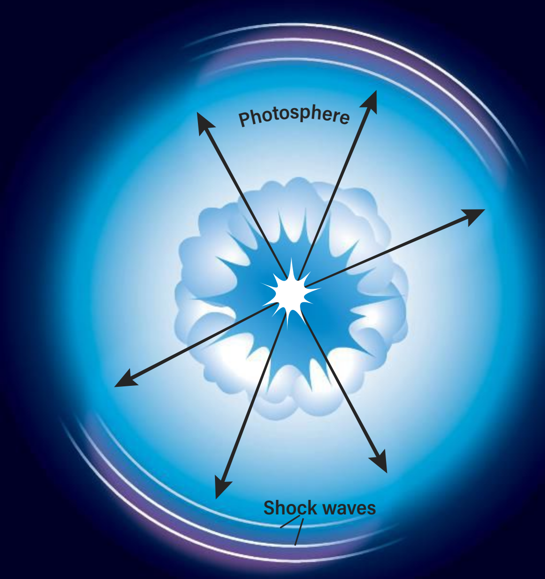
The shock wave also slammed into the denser circumbinary disk, but its material was being swept up more slowly. “The thinking is that the photosphere … very quickly overtakes the [circumbinary] disk,” so that the disk is effectively concealed inside the photosphere even though it is producing light, Gagliano says.

Only as the outer material cooled and the photosphere began to recede did the disk become visible, powering the dramatic rebrightening. “There’s a transition where your outermost photosphere is not that low-density material. It’s the interaction that’s happening between the disk and the explosion. And so your photosphere moves inward and inward and inward until eventually you’re just seeing the interaction with the disk, that powers then that second peak,” Gagliano says.

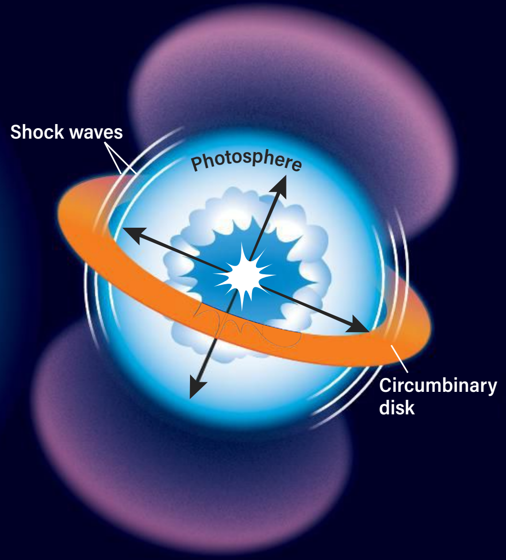
A new window on stellar death

The violent inspiral and complex gas structures pointed to one culprit: a black hole companion, which triggered the star’s explosive death. In this scenario, stresses induced by the black hole’s gravity as the two circled increased the pressure in the star’s core until it could no longer support itself, inducing a core-collapse supernova. It’s an event that has been theorized but never observed, and it addresses a long-standing question in astronomy.

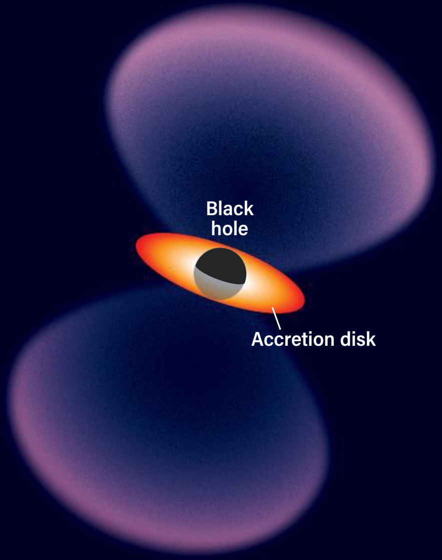
“For decades, there’s been these debates about whether material coming



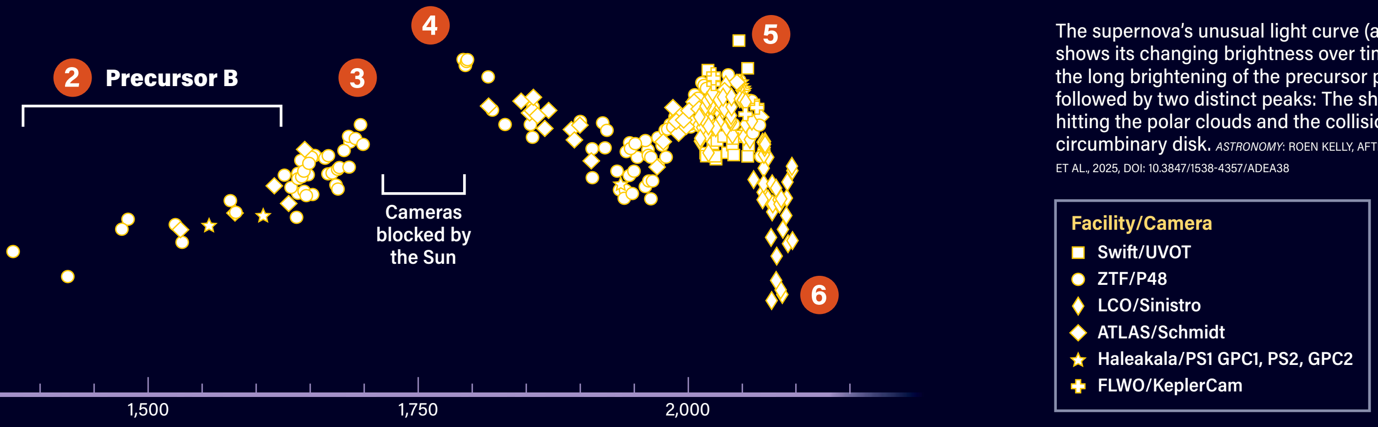
4 The first peak
The supernova's shock wave expands rapidly, slamming into the less dense clouds of gas at the poles. The collision heats this material, creating a brilliant opaque photosphere that obscures the circumbinary disk. This creates the first peak in the supernova's brightness.



5 The second peak
After about 240 days, the photosphere has receded far enough to unveil the light from a far-longer-lived collision: the supernova shock wave slamming into the dense equatorial disk. This sustained, violent interaction powers a second, brilliant peak in brightness.



6 The aftermath
The star is gone, and all that remains is a single, slightly more massive black hole.



The supernova's unusual light curve (at left) shows its changing brightness over time. It reveals the long brightening of the precursor phase, followed by two distinct peaks: The shock wave hitting the polar clouds and the collision with the circumbinary disk. *ASTRONOMY*: ROEN KELLY, AFTER A. GAGLIANO ET AL., 2025, DOI: 10.3847/1538-4357/ADEA38

off of a star in the millennia to years before it explodes is caused by internal changes … or is it internal changes driven by dynamical interactions with a companion?" Gagliano says. This discovery, he adds, provides confirmation that companions can indeed play a "determining role in the explosion itself."

While the merger-induced supernova is the leading theory, the team also considered an alternative scenario called tidal disruption, Gagliano says, in which the black hole tears the star apart before it can explode. In that case, the brilliant flash of light that looked like a supernova was not a traditional supernova, but instead the two objects spiraled together until the star was completely consumed. If this were the case, however, the team would expect "earlier, brighter emission that we didn't see in this event," Gagliano says.

Fittingly, a story that began with an automated algorithm points to a future where astronomy and artificial intelligence work hand in hand. As next-generation observatories like the Vera C. Rubin Observatory begin to generate an unprecedented flood of data, intelligent systems like LAISS will be indispensable.

In the case of SN 2023zkd, the warning from the LAISS algorithm turned the team's attention to the event long before the rebrightening. "To our eyes, the supernova was not too unusual, but our algorithm was luckily able to pick up on it as something unusual."

With this discovery, astronomers have a blueprint for an entirely new class of stellar death. The goal now is to find more. If, with the help of AI, astronomers can build a sample of these events and capture detailed spectra, Gagliano explains, "then you can start to make population-level statements that we just have never been able to make before." SN 2023zkd has opened a new window onto the complex lives of massive stars.

"We're now entering an era where we can automatically catch these rare events as they happen, not just after the fact," Gagliano said in a press release. "That's incredibly exciting."

Brooks Mendenhall *is a staff writer at* Astronomy *magazine, and is based in Chattanooga, Tennessee.*

THE EVOLUTION OF SOLAR

After four centuries of advances, astronomers now capture the Sun's swirling, dynamic features in stunning detail.

STORY AND IMAGES BY MARK JOHNSTON

THE SUN HAS CAPTIVATED humanity for millennia. And yet, despite being our closest star, studying it is not easy. Its blinding brilliance long defied detailed study. But over the centuries, astronomers have developed ingenious tools to unveil its secrets.

From crude sketches of sunspots to today's stunning images, the journey of solar imaging reflects both human curiosity and technological ingenuity. Each advance has deepened our understanding of how dynamic our star is — and how it impacts life on Earth.

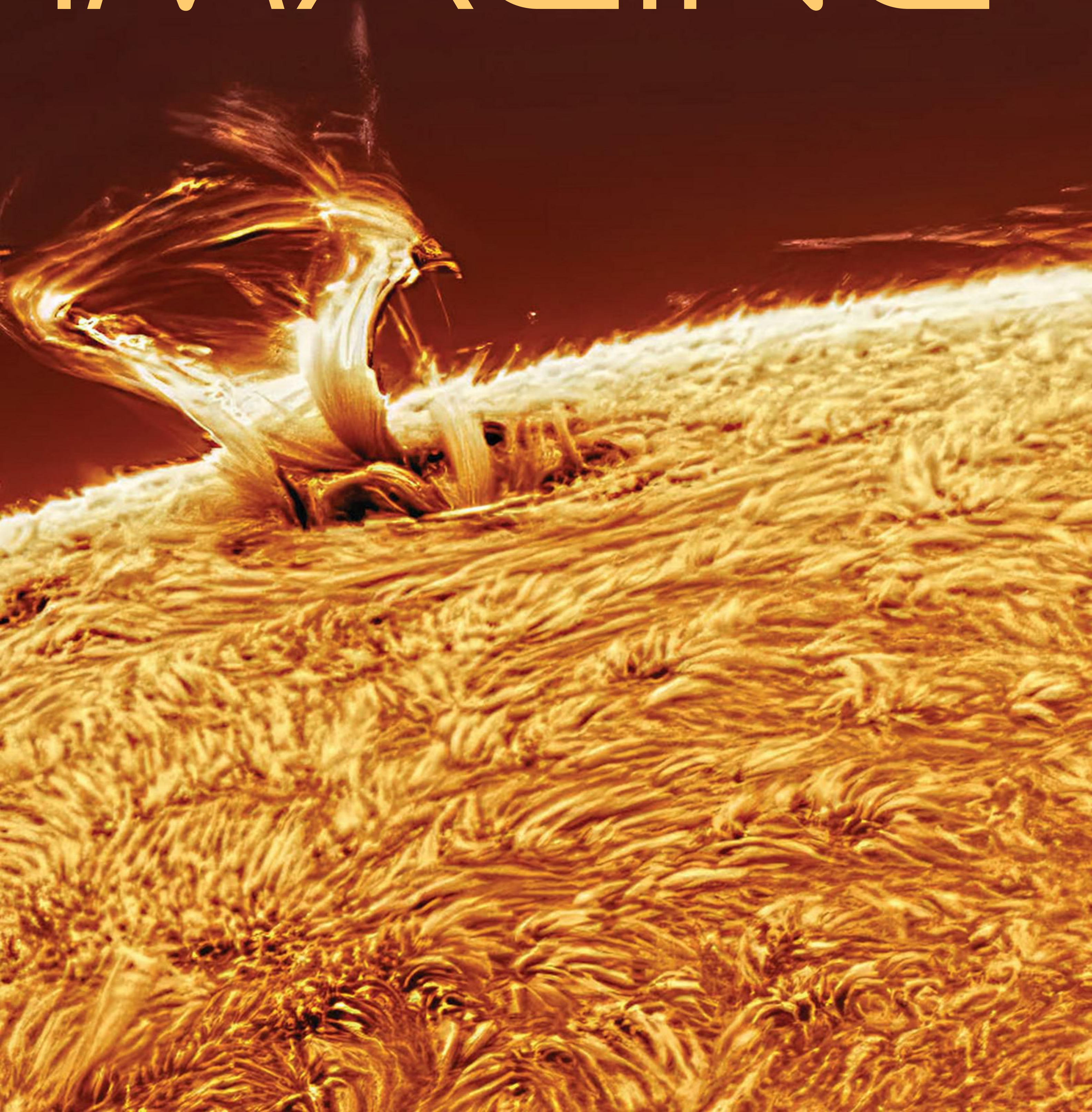
EARLY VISUAL OBSERVATIONS

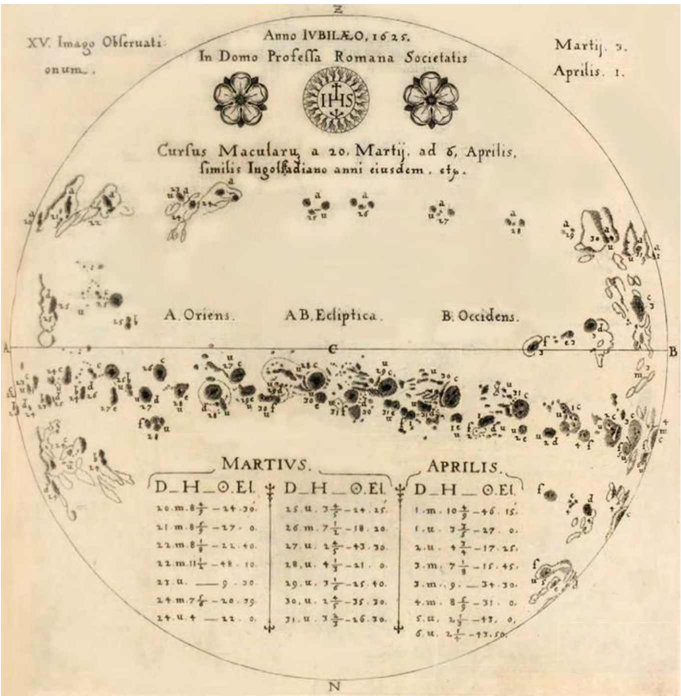
The earliest solar observations relied on the naked eye. Chinese astronomers recorded sunspots as early as 364 B.C.E., noting dark blemishes visible during sunset or through haze. (Note: Never try to observe the Sun without proper solar filters or equipment.) It wasn't until the early 17th century, with the advent of telescopes, that systematic study began.

Among the first solar astronomers was Galileo Galilei, who in 1610 used a crude refractor to project

Sunspots are active regions where the Sun's magnetic field contorts itself into loops and arcs. Solar imaging captures these phenomena, providing both dramatic imagery and scientific insight.

IMAGING

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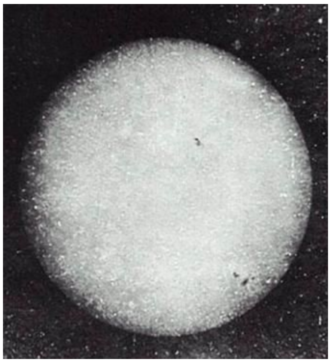


ABOVE LEFT: Christoph Scheiner made detailed sketches of sunspots starting in 1611; this example is from 1625. COURTESY OF THE LINDA HALL LIBRARY OF SCIENCE, ENGINEERING & TECHNOLOGY

ABOVE RIGHT: The Sun's dynamic magnetic field causes ionized hydrogen to leap off the star's edge, or limb, forming dramatic arcs visible at Hα wavelengths.

LEFT: Hippolyte Fizeau and Léon Foucault's 1845 photo of the Sun was crude by today's standards, but marked the dawn of solar imaging. ESA

solar images onto paper and produce sketches of sunspots as they moved across the Sun's disk. The following year, Christoph Scheiner, a Jesuit mathematician, also began sketching sunspots with remarkable accuracy.

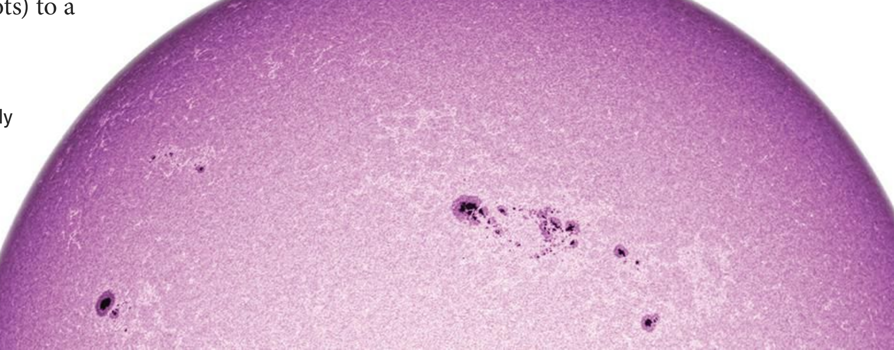
Scheiner wished to preserve his religious belief in the "perfection" of the Sun and argued that sunspots' movements indicated that they were orbiting the Sun like satellites. Galileo countered that the "blemishes" appeared to be on the surface of the Sun, and that the Sun itself rotated. After years of debate and much further study, Scheiner was forced to abandon his belief in the Sun's perfection and admit that sunspots were changing surface features.

By the 19th century, astronomers like Samuel Heinrich Schwabe noticed sunspots waxed and waned in an approximately 11-year cycle. This periodic change in the Sun's activity and appearance progresses from solar minimum (few sunspots) to a solar maximum (many sunspots) and back, affecting space weather and Earth's upper atmosphere. Schwabe's visual observations, often made through smoked glass or crude filters, laid the groundwork for modern solar physics. Yet, the human eye and hand-drawn sketches could only capture so much. The Sun's blinding brightness demanded a new approach.

THE DAWN OF SOLAR PHOTOGRAPHY

The invention of photography in the 1830s revolutionized astronomy, and the Sun was an early target. In 1845, French physicists Hippolyte Fizeau and Léon Foucault captured the first daguerreotype of the Sun, a grainy image revealing sunspots and the solar limb. These early photographs, though rudimentary, offered a permanent record far superior to sketches.

By the late 19th century, advances in photographic emulsions allowed astronomers like George Ellery Hale to build crude spectroheliocopes to document solar features with greater clarity. These devices viewed the Sun through a narrow slit, using a prism to spread its light out into different wavelengths and allowing observers isolate wavelengths emitted by



Early efforts at narrowband imaging of the Sun frequently focused on the Calcium K line at 393.4 nanometers, a wavelength that reveals activity in the Sun's chromosphere.

specific elements, like hydrogen or calcium. While the view was restricted to a narrow portion of the Sun, by scanning the slit across the disk, observers could construct single-wavelength images of features like prominences — massive loops of plasma arcing above the Sun's surface.

However, early solar imaging remained limited by the Sun's overwhelming brightness and the lack of specialized filters to isolate the specific wavelengths of light emitted by the Sun's ionized gases. The 20th century would see a leap forward with the development of optical filters and dedicated solar telescopes.

MODERN SOLAR IMAGING

Today's solar imaging by amateur astronomers builds on decades of optical innovation. Solar-observing techniques can be sorted broadly into two categories: Broadband observations capture the Sun's full visible spectrum, while narrowband observations observe individual wavelengths of light emitted by the Sun's plasma.

For broadband observations, amateurs and professionals alike use objective filters or Herschel wedges.

Objective filters, typically made of coated glass or Mylar, cover a telescope's aperture. They block most of the Sun's light and allow safe viewing or imaging of the photosphere, the Sun's visible surface. These filters reveal sunspots, faculae (bright patches), and granulation (convection cells).

Herschel wedges offer a sharper alternative. These prisms reflect only a small fraction of sunlight into the eyepiece or camera, while absorbing or redirecting the rest. Paired with neutral-density filters, Herschel wedges produce high-contrast images with minimal light scattering, ideal for capturing fine photospheric details.

Amateurs who already own a small telescope can add these types of filters affordably. But broadband imaging, while versatile, lacks the wavelength specificity needed to probe deeper solar phenomena, prompting the rise of narrowband techniques.

Narrowband solar imaging isolates specific wavelengths to highlight distinct layers of the Sun's atmosphere. One early target was the Calcium-K (CaK) line at 393.4 nanometers, which reveals magnetic activity in the chromosphere, the layer above the photosphere. CaK filters, often used in specialized solar telescopes, show bright plage regions around sunspots and intricate chromospheric networks. These images offer insights into magnetic activity but often require ultraviolet-sensitive cameras due to the wavelength's proximity to the violet end of the visible spectrum.

While CaK imaging remains valuable, it has been overshadowed by the gold standard of solar observation: Hydrogen-alpha (Hα) imaging. Hα, centered at 656.28 nanometers, unlocks a vivid view of the chromosphere's dynamic features, from fiery prominences to dark filaments and explosive flares.

THE STATE OF THE ART

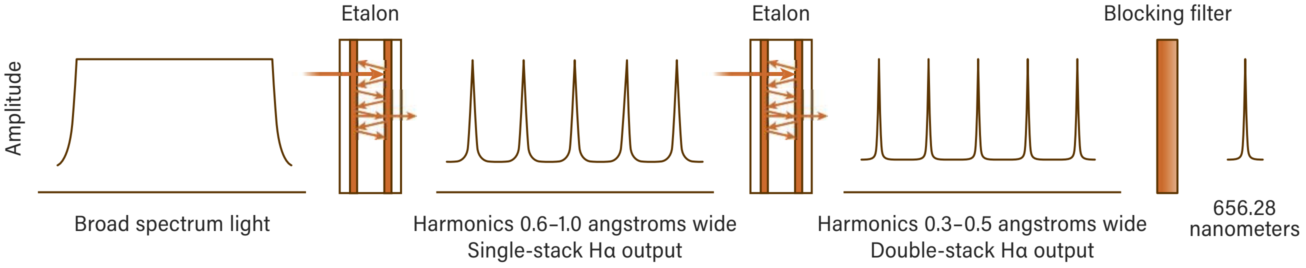
Hα imaging dominates modern solar observation. The Hα line corresponds to the first Balmer transition of hydrogen, abundant in the chromosphere. By isolating this narrow wavelength — typically with devices called etalons — astronomers can study the motion of the Sun's

HOW ETALONS WORK

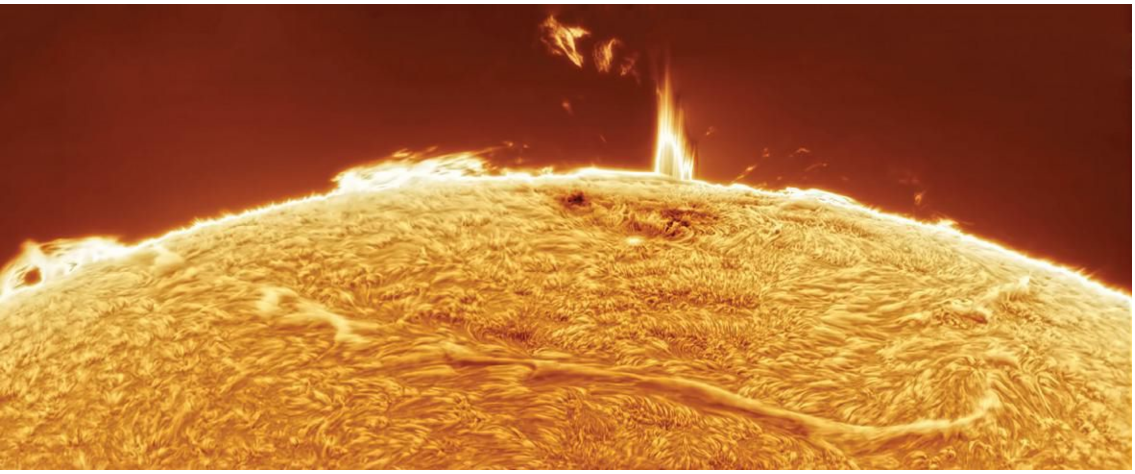
An etalon consists of two parallel, partially reflective surfaces spaced a tiny distance apart. When light enters this cavity, it bounces back and forth between the surfaces, creating reflected beams. These beams overlap and combine, producing an interference pattern — a set of bright and dark spots or "fringes" caused by light waves reinforcing or canceling each other.

This interference occurs because only wavelengths that fit an exact number of half-wavelengths in the spacing between the plates line up perfectly (constructive interference) and pass through strongly. Wavelengths that don't fit this pattern interfere destructively and are blocked.

The result is a series of narrow transmission peaks — the desired wavelength (such as the Hα line) plus other wavelengths that are harmonics of that wavelength. Stacking two etalons narrows these peaks further. Finally, a blocking filter selects just one of these harmonics while blocking others.



ASTRONOMY: THEO COBB



The charged particles of plasma trace out the lines of the Sun's magnetic field. When rising off of the Sun's limb, they appear as prominences (top). Twisted loops of plasma can also appear winding across the surface as filaments (bottom).

CAMERAS AND SOFTWARE

Camera suppliers are advancing the state of the art with cameras designed for solar imaging with high resolution, fast frame capture, deep well depth, and pixel sizes that are well-matched for different telescope focal ratios. Since we're typically only looking at one wavelength, these monochrome cameras are the first step in capturing detailed views of the Sun.

Solar imaging has also benefited from an array of recent software. A typical imaging workflow might start with a program like SharpCap Pro or Firecapture, which are optimized to capture high-speed video of the Sun, with each frame fast enough to "freeze" turbulence in the atmosphere. The image-stacking program Autostakkert!4 can extract only the most in-focus frames. The resulting TIFF file can then be sent to the processing program ImPPG, which can stretch and tease out faint prominences while sharpening the surface. This image in turn can then be opened in Affinity Photo, Photoshop, or PixInsight, which will convert mono to color and further sharpen and improve surface contrast.

Finally, software like Topaz Photo AI can remove noise, resulting in breathtaking color photos. Amateurs now routinely capture prominences curling into space, filaments snaking across the disk, and flares erupting in real time. Some advanced amateurs are even producing images and time-lapse animations that rival professional observatories. Online communities share these images, supporting a global network of solar observers and enthusiasts. —*M.J.*

plasma, its magnetic fields, and transient events like solar flares.

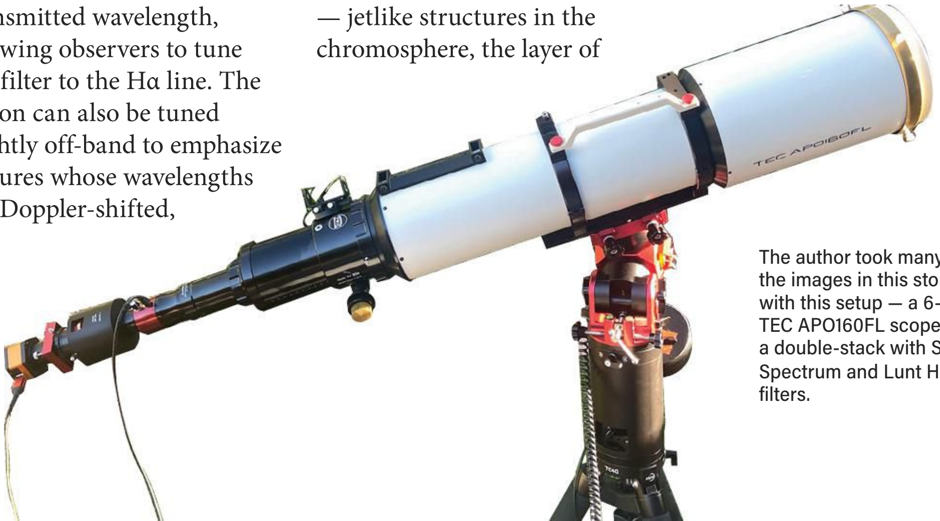
Three main Hα etalon designs power today's solar telescopes.

The first and simplest are tilt-tuned etalons. These filters use a Fabry-Pérot etalon — a pair of partially reflective plates that transmit only a narrow wavelength band. Tilting the etalon shifts the transmitted wavelength, allowing observers to tune the filter to the Hα line. The etalon can also be tuned slightly off-band to emphasize features whose wavelengths are Doppler-shifted, like fast-moving prominences. Tilt-tuned systems, common in entry-level Hα telescopes, are effective but can be expensive if they have to cover larger apertures.

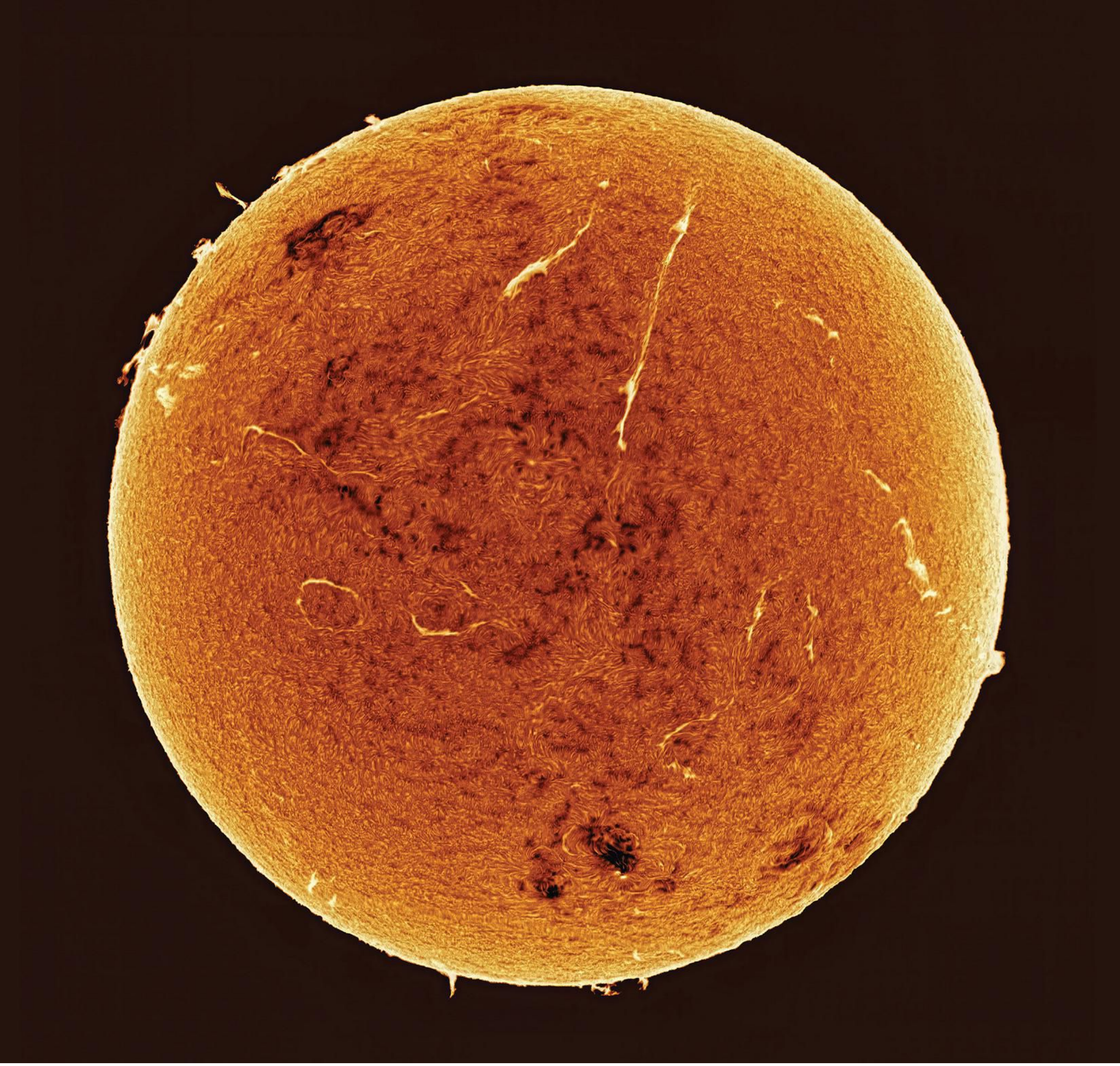
Pressure-tuned etalons are more advanced and used in telescopes like those produced by Lunt Solar Systems. These devices adjust the etalon's refractive index by varying the air pressure between the plates. This method provides uniform tuning across the field, improving image consistency. Pressure-tuned etalons are often combined in series (double-stacked) and excel in high-resolution imaging. They are capable of capturing prominences and intricate details like spicules — jetlike structures in the chromosphere, the layer of the Sun's atmosphere above its visible surface.

The third approach is solid etalons, which use a single solid medium — typically crystals of the silicate mica — to isolate Hα light. Solid etalons, such as those made by Daystar or Solar Spectrum, require power and a warm-up period to bring them on-band, but are less sensitive to temperature or pressure changes, making them ideal for long imaging sessions. While pressure or tilt systems are usually integrated into a solar telescope design, solid etalons are often sold as a standalone option for refracting telescopes.

Another recent development in solar imaging is the availability of high-quality spectroheliographs at modest prices. Similar in principle to Hale's spectrohelioscope, these instruments use a tunable slit and a prism or diffraction grating to isolate a single wavelength of light, such as Hα or CaK. By scanning across the Sun line by line, they capture narrowband slices that software then assembles into an ultrahigh-contrast image of the Sun. Unlike etalon-based systems, spectroheliographs typically do not support real-time visual observation and are usually optimized for full-disk imaging rather than close-up views.



The author took many of the images in this story with this setup — a 6-inch TEC APO160FL scope and a double-stack with Solar Spectrum and Lunt Hα filters.



Spectroheliographs isolate light of a single wavelength and create an image of the Sun's full disk by scanning it, line by line. This can result in images with stunning contrast.

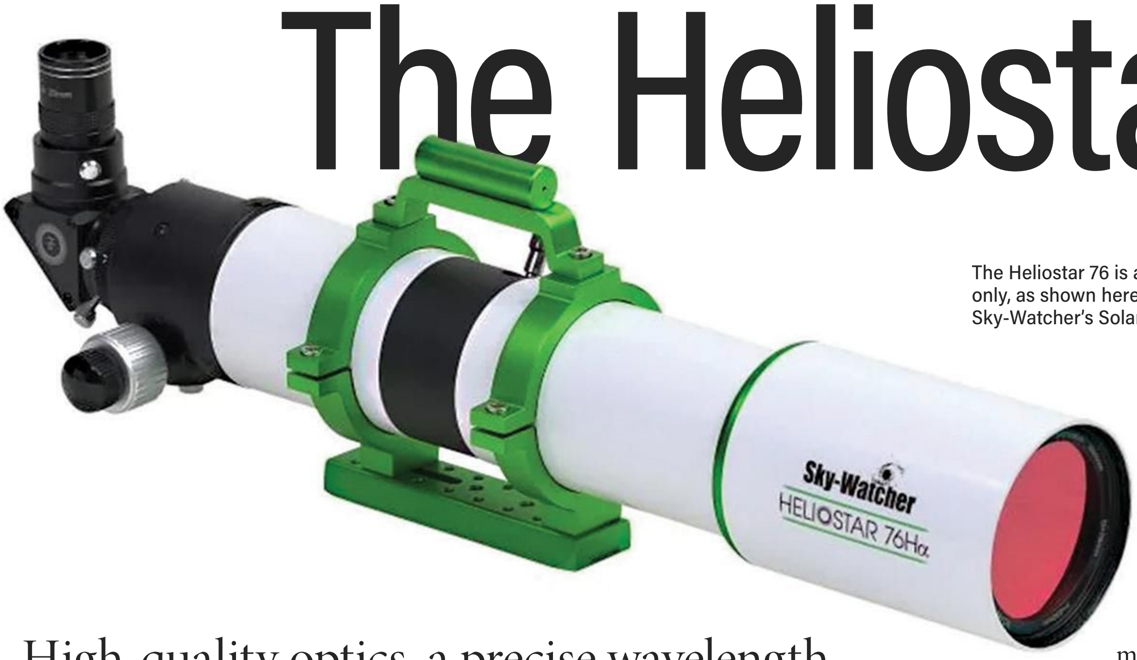
THE FUTURE OF SOLAR IMAGING

Future innovations promise even sharper views. These include improved etalon designs and adaptive optics for ground-based telescopes, as seen on facilities like the Daniel K. Inouye Solar Telescope. For now, the combination of narrowband filters, dedicated solar cameras, powerful processing software and educational YouTube tutorials have made the Sun more approachable, inviting new enthusiasts to witness the Sun's restless beauty firsthand.

Whether it's a parade of sunspots, feisty active regions, or ever-changing prominences and spicules on the limb, observing the Sun promises something new every day for both curious beginners and seasoned astrophotographers. With a modest Hα scope, you too can explore a star that's both familiar and endlessly surprising. As solar imaging continues to evolve, one thing is certain: We'll keep finding new and better ways to capture the Sun's light.

Mark Johnston *is a NASA solar system ambassador, vice president of the Phoenix Astronomical Society, ACEAP astronomy ambassador to Chile, and the Telescope.live ambassador for solar imaging.*

The Heliostar 76



The Heliostar 76 is available as an optical tube only, as shown here, or you can bundle it with Sky-Watcher's SolarQuest mount. SKY-WATCHER

High-quality optics, a precise wavelength filter, and lots more make Sky-Watcher's solar scope a must-have for daytime observing.

BY PHIL HARRINGTON

Although I've spent decades as a deep-sky observer, I've always been fascinated by the Sun. Solar observing offers clear advantages: It's accessible anywhere, immune to light pollution, and doesn't require staying up late. Best of all, the Sun is dynamic. The view changes daily.

While white-light filters are great for showing evolving sunspots, most of the action is only visible through telescopes equipped with specially designed Hydrogen-alpha (Hα) filters. Through these, it's an entirely different star. An Hα filter reveals the chromosphere, the dynamic layer just above the Sun's visible surface, the photosphere. The first time I looked through one decades ago, I was stunned by the view of prominences, plages, and filaments strewn across the solar disk. I just had to get one.

Back then, such instruments were rare and costly, found mainly in large observatories. But times have changed. Today, more affordable Hα telescopes are widely available, including a remarkable model introduced in 2024 by Sky-Watcher Instruments.

What's inside

The Sky-Watcher Heliostar 76mm H-Alpha Solar Telescope brings Hα observing into the reach of amateur astronomers. The core of the instrument is a finely crafted 3-inch (76 mm) f/8.3 fully multicoated doublet objective.

A defining feature that sets the Heliostar apart from other amateur Hα solar telescopes is its integration of a high-performance single-stack Solis etalon. An etalon is a special optical device used in solar telescopes to isolate the red Hα wavelength (656.28 nanometers). It comprises two extremely flat, highly reflective glass plates positioned close together and kept precisely parallel. When light enters the etalon, it bounces back and forth between these surfaces. Because of the way light waves interact, a process called interference, the etalon blocks out most sunlight and allows only a narrow range of wavelengths around the Hα wavelength to pass through.

Some observers use setups with two etalons to further isolate Hα light, improving clarity and contrast. However, such systems can result in faint images through an eyepiece (remember, we're isolating a tiny fraction of the Sun's light).

The Heliostar stands out by using a single high-finesse Solis etalon ("finesse" meaning how precisely it isolates wavelengths), achieving a bandwidth of less than 0.5 Ångstroms. Such a narrow window assures sharp detail. Its Trifid pressure tuner maintains performance across temperatures, avoiding the problems faced by some Hα systems. The Heliostar also preserves brightness while delivering clarity and contrast comparable to dual-etalon systems, but without the light loss.

The Heliostar comes with a sturdy dual-speed 2-inch Crayford focuser that makes precise adjustments easy. Fine focus is crucial when viewing narrowband solar features, where even slight deviations can soften the image.

The 90° diagonal included with the Heliostar is not your ordinary star diagonal. Inside, a permanently mounted blocking filter that meets ISO 12312-2 solar safety standards further blocks non-Hα wavelengths. The filter ensures that the final image reaching the eyepiece is both bright and safe.

The telescope tube has a matte white finish that helps reduce heat buildup in sunlight. The tube rings and Vixen-style mounting plate are finished in bold green anodizing. Together, these colors give the Heliostar a striking appearance that's sure to attract attention.

Sky-Watcher also includes several useful accessories, among them a clip-on sunshade. This item attaches to the tube and blocks sunlight from entering the observer's eye during use. The shield

brings you the Sun

makes viewing our star on a sunny day much more comfortable.

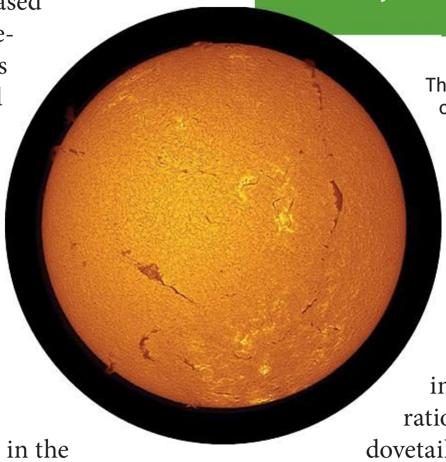
Sky-Watcher permanently mounted a small solar finder on one of the tube rings. This device allows for safe and easy solar alignment by projecting a small image of the Sun onto a built-in screen. When the Sun's dot is centered on the screen, the telescope is aimed.

Other accessories include a 20mm wide-angle eyepiece, which offers a 70° apparent field of view. It's a good start for general solar viewing, but owners can use any 1¼" eyepiece. There's also a smartphone adapter for those interested in trying basic imaging. Everything fits securely in a rugged, foam-fitted case.

For this review, Sky-Watcher also supplied its SolarQuest mount, designed specifically for solar observing. (The mount can be purchased together with the telescope as a kit.) It uses GPS and a HelioFind sensor to automatically orient, locate, and track the Sun. Setup is simple: Place it on a tripod, turn it on, and it self-aligns and starts tracking the Sun within minutes. You'll find a review of this mount in the September 2023 issue.

PRODUCT INFORMATION

Sky-Watcher Heliostar 76
Aperture: 76 millimeters
Lens: Achromatic doublet
Focal ratio: f/8.3
Focal length: 630 millimeters
Bandpass: Less than 0.5 Ångstroms
Length: 24 inches (61 cm)
Weight: 8.4 pounds (3.8 kg)
Also included: mounting rings, 20mm eyepiece, diagonal, sunshade, solar finder, cellphone adapter, case
Price: $3,395 (telescope only) / $3,895.00 (with SolarQuest mount)
Contact: Sky-Watcher
2835 Columbia Street
Torrance, CA 90503
1-855-327-1587 x306
www.skywatcherusa.com



This Hydrogen-alpha image of the Sun was taken through the Heliostar 76. TONY CARRO

Setup and use

The Heliostar telescope arrived assembled, double-boxed, and securely packed in a foam-lined carrying case. The SolarQuest mount and tripod came the same day in a separate, well-padded box.

Assembly was straightforward. I extended the tripod legs, attached the accessory tray, and placed the extension pier on top. After threading the SolarQuest mount onto the pier, I adjusted the tripod until the mount's bubble level showed it was leveled.

Once the mount was assembled, I attached the Heliostar in its sidesaddle configuration. I oriented the dovetail groove, seated the mounting plate, and tightened the knob securely. After powering on, the mount acquired a GPS signal and slewed automatically to the Sun, confirming alignment with a steady red LED.

After I inserted the supplied 20mm eyepiece into the diagonal and adjusted the focus, the Sun's surface snapped into stunning detail after a slight tweaking of the pressure tuner. Through the eyepiece, I observed intricate sunspot groups, fine granulation, sinuous filaments, and delicate prominences along the Sun's limb. The image was remarkably sharp and clear, revealing far more than I expected at this aperture.

For comparison, I also set up my own "Brand X" single-stack Hα solar telescope next to the Heliostar. Swapping the 20mm eyepiece back and forth, I found the Heliostar's view was far sharper and higher in contrast. Admittedly, the Heliostar had a larger aperture (76mm versus 60mm), but the difference in image quality left a strong impression.

Photography

Imaging the Sun with the Heliostar 76 ranges from basic to advanced. The included smartphone adapter allows for simple photos of prominences and filaments, though image quality is limited.

A DSLR or mirrorless camera at prime focus offers better resolution, but managing exposure can be difficult. Images can still appear overexposed, even with the camera set to its lowest ISO and fastest shutter speed.

To achieve those sharp, high-contrast solar images seen online, a monochrome astronomy camera, high-speed video capture, and image-stacking software such as AutoStakkert! or RegiStax are essential. With the right setup, the Heliostar can deliver remarkably detailed views of the active photosphere.

Conclusion

I absolutely loved using the Heliostar 76 paired with the SolarQuest mount. Together, they form a complete, brilliantly designed solar observing system that's ready to go right out of the box.

Whether for visual exploration or solar imaging, this setup delivers crisp, detailed views that left me genuinely impressed. And the fact that it outperforms many pricier double-stack systems makes it a compelling value for dedicated solar observers.

Phil Harrington *is a contributing editor of* Astronomy *and a longtime equipment guru.*

First night with a new scope

Temper your excitement with this plan.

ABOVE: Using a red light to illuminate the foreground, the author captured herself looking through her 12-inch reflector at the 2025 Rocky Mountain Star Stare. MOLLY WAKELING

RIGHT: As night falls, the author checks out the planets with her Celestron NexStar 8SE. MOLLY WAKELING

BY MOLLY WAKELING
Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.

It's Christmas morning. Snow is gently falling outside, cinnamon rolls are baking in the kitchen, and you just opened the present you've been dreaming of — a telescope! But after the initial excitement wears off, you begin to wonder: How the heck do I use this thing?

The first night with your shiny new telescope should actually start during the day. There are several aspects you should familiarize yourself with. First, determine how the telescope moves, how it locks into place, and how to insert and remove the star diagonal and the eyepiece.

Next, take it outside and point at a distant object. Move the focuser in and out with the eyepiece in place to find focus. If you can't get it to focus, try a target farther away. If you're lucky and received multiple eyepieces, try each of them and notice how the field of view is different and how much you need to move the focuser to find focus.

This is also a good opportunity to align the finder scope, red dot finder, or Telrad. Aim your main scope at a treetop, radio tower, flagpole, streetlight, or other faraway object. Now look through the finder. It will have adjustment knobs or screws. Turn them until the crosshairs, red dot, or bull's-eye are centered on the same target as the main telescope view. This will make finding objects at night much easier. Also take note during the daytime of whether the image in the eyepiece is inverted and/or reversed, and in which direction(s).

First night

You finally have a clear night and decide to brave the cold to do some stargazing with your new scope. First, you'll need to focus it again. The Moon makes a good focusing target if it is up because it's easy to find. Otherwise, just use a star anywhere in the sky. Next, using the finder, seek out a bright star or planet, and then see how moving the scope makes it move in the eyepiece. If the image is inverted, you'll need to get used to thinking about which direction to move the telescope to move an object in the field of view. Then, let the telescope sit still and notice which direction the object moves through the eyepiece as Earth turns. Remember that objects rise in the east and set in the west.

Now you can start exploring. Head to a constellation you're familiar with, or even just an interesting pattern of bright stars. Try moving between the stars, sketching out a path on the sky. This is known as "star-hopping," an essential practice for locating fainter targets you want to observe. Familiarize yourself with what the stars look like in the main telescope versus the finder scope. If you do, you'll find it easier to tell where you're pointing.

You finally have a clear night and decide to brave the cold to do some stargazing with your new scope.

Finally, consult a planetarium app or star chart (like the one in the center of this magazine) to hunt down some bright objects. Great places to start in the wintertime are the Orion Nebula (M42), the Pleiades (M45), and the Double Cluster (NGC 869 and NGC 884) between Cassiopeia and Perseus. Also take some time to slowly cruise around and see what you just happen across. There are many star clusters scattered all over the sky. As your skill improves, you might even encounter some galaxies and bright nebulae. Take notes on what you see in a notebook. Someday when you're an old pro, it will be fun to look back and see where you started.

The first night with a new telescope can be frustrating, but take your time and get to know your gear. Keep trying, hang out with your local astronomy club, and soon you'll be chasing faint fuzzies all over the sky.

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Alan Dyer

Strathmore, Alberta

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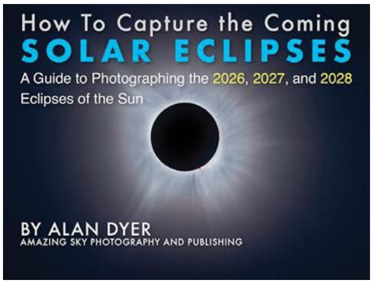

How To Capture the Coming
SOLAR ECLIPSES
A Guide to Photographing the 2026, 2027, and 2028 Eclipses of the Sun
BY ALAN DYER
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a. Total number of copies (net press run)	69,133	66,793
b. Paid circulation (by mail and outside the mail)		
1. Mailed outside-county paid subscriptions	47,168	45,013
2. Mailed in-county paid subscriptions	-0-	-0-
3. Paid distribution outside the mails including sales through dealers and carriers, street vendors, counter sales, and other paid distribution outside USPS	4,850	4,126
4. Paid distribution by other classes of mail through the USPS	-0-	-0-
c. Total paid distribution [sum of 15b (1), (2), (3), and (4)]	52,018	49,139
d. Free or nominal rate distribution (by mail and outside the mail)		
1. Outside-county	-0-	-0-
2. In-county	-0-	-0-
3. Other classes mailed through the USPS	201	210
4. Outside the mail	-0-	-0-
e. Total free or nominal rate distribution [sum of 15d (1), (2), (3) and (4)]	201	210
f. Total distribution (sum of 15c and 15e)	52,219	49,349
g. Copies not distributed	16,914	17,444
h. Total (sum of 15f and g)	69,133	66,793
i. Percent paid (15c divided by 15f times 100)	99.62%	99.57%
16. Electronic copy circulation:		
a. Paid electronic copies	880	975
b. Total paid print copies (15c) plus paid electronic copies (16a)	52,898	50,114
c. Total print distribution (15f) plus paid electronic copies (16a)	53,099	50,324
d. Percent paid, both print and electronic (16b divided by 16c times 100)	99.62%	99.58%

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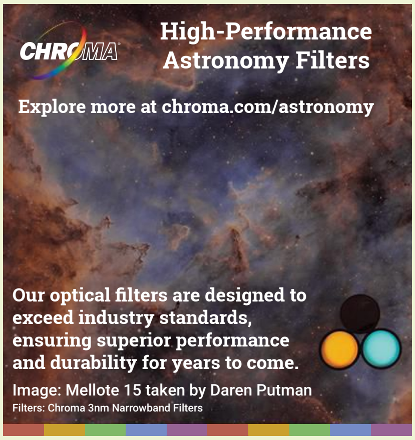

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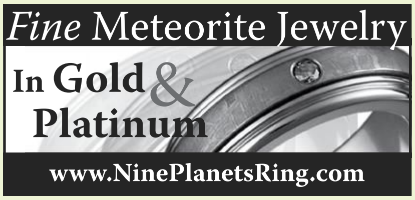

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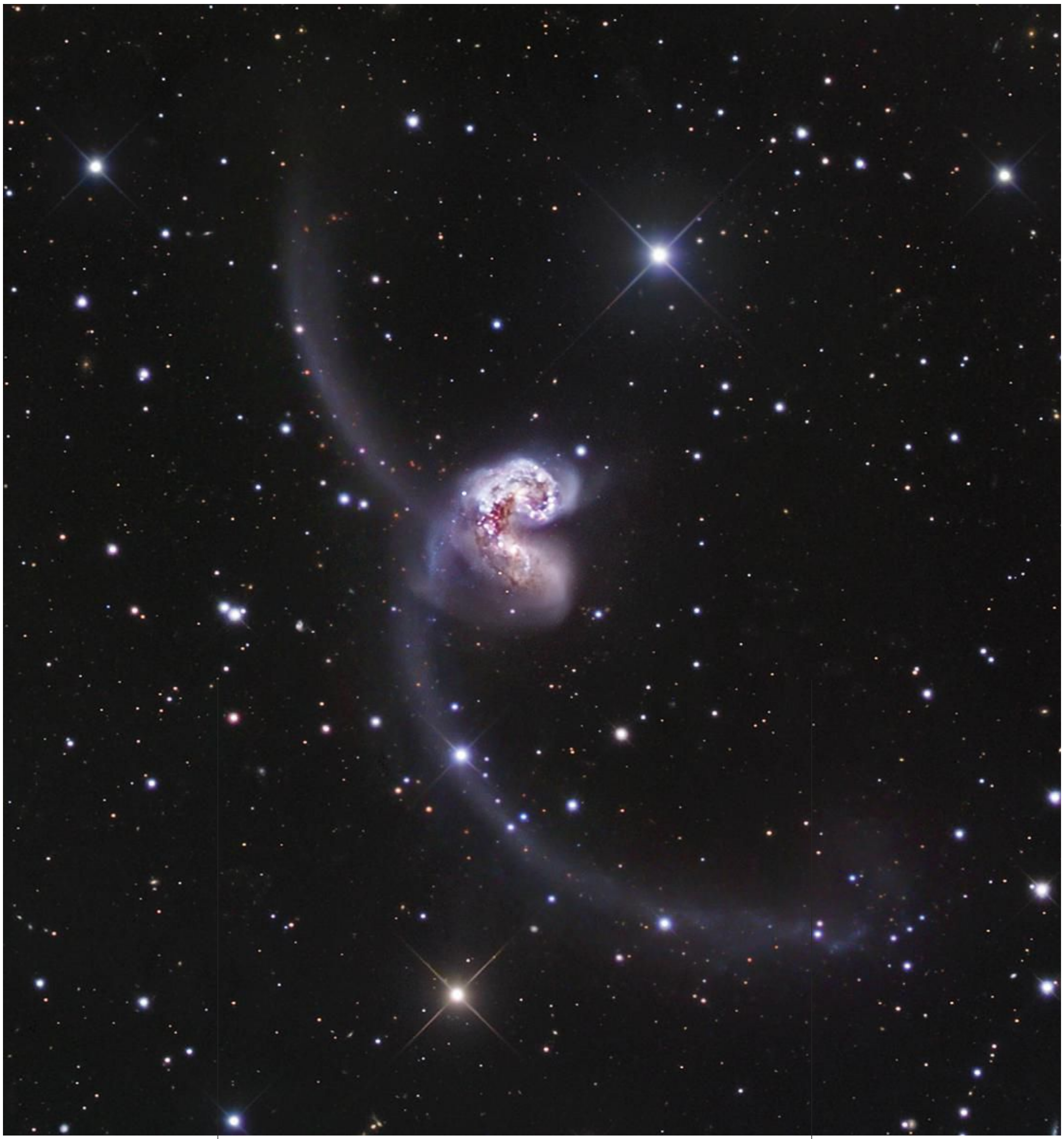


The Antennae (NGC 4038 and NGC 4039) are a famous pair of merging galaxies where gravitational forces have created extensive tidal tails of stars pulled outside their home galaxies. ROBERT GENDLER

Where stars live

Q | DO ALL STARS EXIST IN GALAXIES, OR DO SOME EXIST IN INTERGALACTIC SPACE?

Thomas Griffilth
Atlantic City, New Jersey

A | Nearly all stars are found inside or around galaxies, because that's where the conditions are right for stars to form. Within galaxies, stars form inside cold, dense molecular gas clouds like those found in the spiral arms of our Milky Way. In the voids between galaxies, the gas is much lower in density and too warm to form stars, so true intergalactic space has very few stars in it.

But there are a few ways for stars to get out of galaxies and into intergalactic space. One way is through galaxy collisions, where gravitational forces can strip stars out of galaxies and fling them out into space in long streams called tidal tails. Such collisions are frequent inside galaxy clusters, where the effects of many galaxy collisions plus the intense gravitational pull of the cluster as a whole can combine to strip many stars out of galaxies and into the space between the galaxies in the cluster. These orphaned stars make up what astronomers call the intracluster light, which might hold 20 percent or more of the total starlight in a giant galaxy cluster.

Another way stars can get out of galaxies is through being ejected by a supermassive black hole at the center of a galaxy. In this scenario, a binary star system passes too close to the black hole and in a complex gravitational dance, one of the stars is captured by the black hole and the other is ejected at very high speed and can escape its parent galaxy. We see examples of high-velocity stars leaving our own Milky Way Galaxy this way, and it's even possible that some of the stars passing through the Milky Way may have been ejected by our neighboring Andromeda Galaxy. And some galaxies may have binary supermassive black holes in their nuclei, which can eject even more stars from their host galaxy.

So, even though they don't form far outside galaxies, there are a variety of ways that stars can be ejected from their home galaxy, meaning that intergalactic space isn't completely devoid of them.

Chris Mihos
Warner Professor of Astronomy, Case Western Reserve University, Cleveland, Ohio

Q | WHY DON'T PLANETS FALL INTO THE STARS THEY ORBIT IF THEY'RE CONSTANTLY BEING PULLED BY GRAVITY?

Lindsey Coughter
Rocky Mount, North Carolina

A | This is a brilliant question because the notion of an orbit is counterintuitive. We know that massive objects (really, any objects with mass) gravitationally attract other massive objects; Newton's law of universal gravitation is firmly established on this point. For instance, throw a baseball horizontally at about shoulder height and it will follow a curved path until it strikes the ground because Earth quickly draws the ball back to its surface. (Technically, Earth and the ball move toward each other and collide, but Earth is so much more massive than the ball that the former's motion is practically zero.)

A star and attendant planet, both being massive, should also come together rapidly. Instead, planets tend to maintain orbits around stars without actually crashing into them.

To understand how planets are able to maintain a respectful distance from their parent stars, let's return to the aforementioned baseball. Earlier, we imagined throwing it at normal human strength. Now, imagine you throw it again, but at a much higher velocity. The baseball still falls to the ground, but it takes longer — the parabolic path it follows is longer, due to its increased horizontal speed. Continue throwing the ball at ever-increasing velocities and the descending path the ball follows becomes increasingly longer. Finally, imagine that you are able to throw the ball so fast that the surface of Earth curves away from the ball's path faster than the ball can fall. As a result, the ball's curved path carries it *around* Earth. The ball wouldn't ever strike the ground but would constantly miss it altogether and continue falling — and end up orbiting the planet.

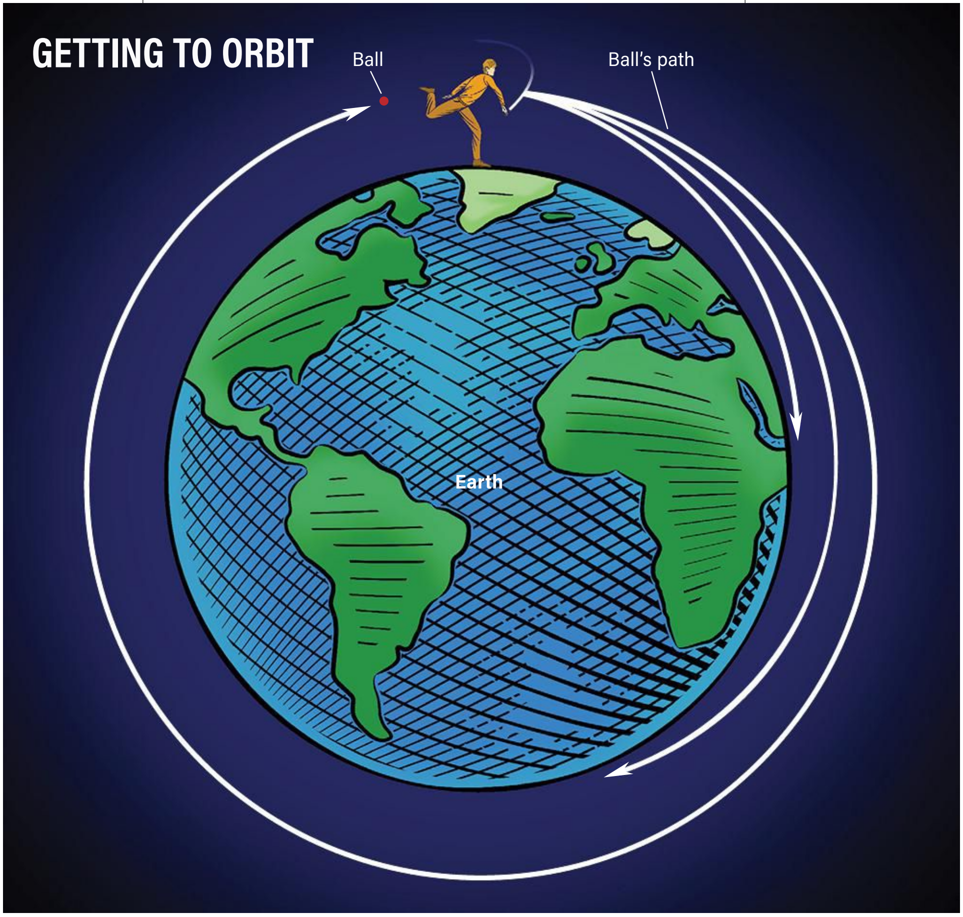
The problem with this picture, apart from the fact that nobody can throw a ball that fast, is that atmospheric drag would quickly reduce the ball's speed and cause it to strike the ground. Many artificial satellites moving around Earth, including the International Space Station, experience this atmospheric drag, albeit to a lesser extent due to the reduced particle density at such high altitudes. (As a result, these objects all eventually crash back to Earth unless they are boosted up again.)

A planet, on the other hand, is essentially moving through a vacuum, and so no reduction of its velocity will occur. The planets are moving fast enough and at a great enough distance that as they "fall toward" the Sun, the Sun will never actually intersect with their orbital path.

To paraphrase the late Douglas Adams, "The knack of flying is learning how to throw yourself at the ground and miss." Orbits operate on essentially the same principle.

Edward Herrick-Gleason
Astronomy Educator, St. John's, Newfoundland and Labrador

> **AS THE PLANETS "FALL TOWARD" THE SUN, THE SUN WILL NEVER ACTUALLY INTERSECT WITH THEIR ORBITAL PATH.**



Imagine throwing a ball horizontally at faster and faster speeds. Eventually, the ball will be traveling so fast that the surface of Earth will curve away from it faster than the ball will fall — so it will just keep falling and its path becomes an orbit. *ASTRONOMY*: THEO COBB

Q | WHO MADE THE PRESENT-DAY OFFICIAL OUTLINES OF THE 88 CONSTELLATIONS AND WHY DO THEY CONTAIN SO MANY ZIGZAGS?

Caitlin McAlister
Cottonwood, Arizona

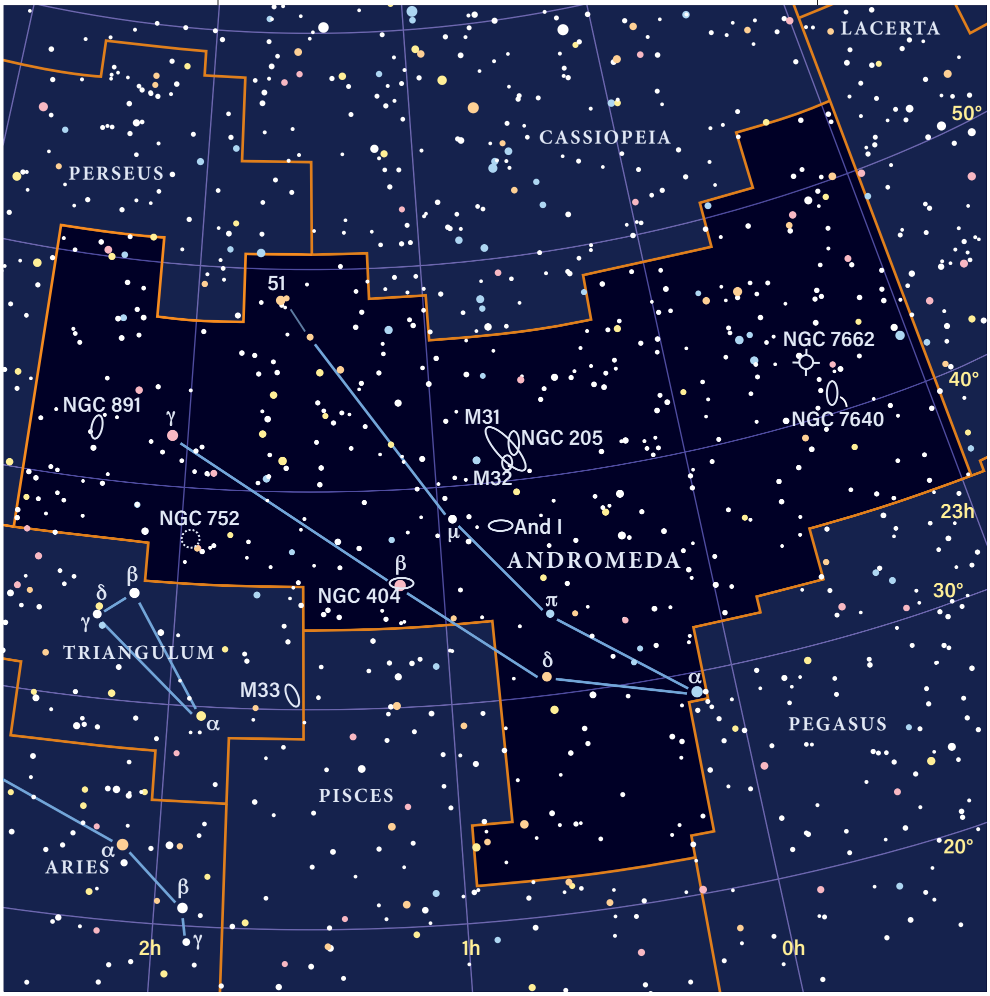
A | If you look at any star atlas published before 1930, you will see what appear to be random lines defining the constellations. Before this date, constellation boundaries had not been formalized. Modern astronomy still uses 47 of the 48 traditional constellations from the ancient Greeks. (The massive constellation Argo Navis has been subdivided into Carina, Puppis, and Vela.) Later astronomers and mapmakers brought the total to the current 88 official constellations. For example, Antlia the Air Pump was created by French astronomer Nicolas Louis de Lacaille in 1754, Vulpecula the Fox was introduced by Polish astronomer Johannes Hevelius in 1687, and Monoceros the Unicorn was invented by Dutch cartographer Petrus Plancius in 1612.

For centuries, the stars of these constellations were bounded by random wavy lines on sky maps. There was some agreement about which stars belonged to each constellation, but there were also possible variations depending on the mapmaker. For example, Gamma (γ) Pegasi was placed in the constellation Pisces on one of Tycho Brahe's star maps. Similar discrepancies can be found throughout the history of celestial cartography.

In 1928, the International Astronomical Union (IAU), the body responsible for the common definitions and constants utilized by professional astronomers, formalized the constellation boundaries. To provide order and structure the IAU committee followed lines of right ascension and declination. These new boundaries were officially published in 1930. So, what may look like a random patchwork of right-angle lines has provided order to the sky.

Raymond Shubinski
Contributing Editor

IN 1928, THE INTERNATIONAL ASTRONOMICAL UNION FORMALIZED THE CONSTELLATION BOUNDARIES.



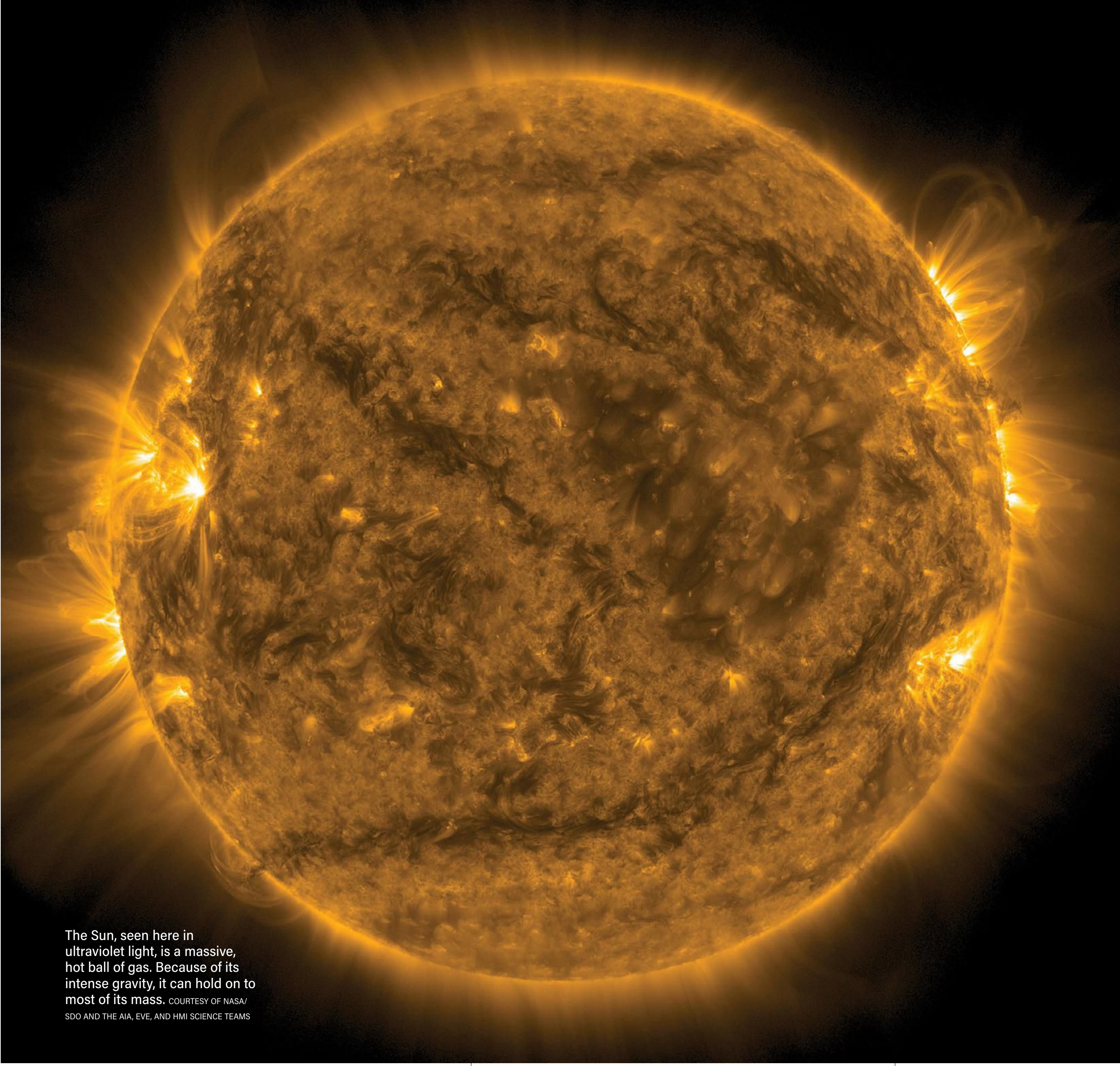
The constellations as designated by the International Astronomical Union, such as Andromeda the Princess, have formal boundaries that follow lines of right ascension and declination on the sky. *ASTRONOMY*: ROEN KELLY

Q | SINCE THE SUN IS SO HOT, HOW CAN IT CONTAIN OXYGEN, CARBON, AND OTHER ELEMENTS WITHOUT DESTROYING THEM?

Bob Found
Indian Harbour, Nova Scotia

A | If you were to take a random blob of gas and heat it to solar temperatures (roughly 10,000 degrees Fahrenheit [5,500 degrees Celsius] at the surface or over 27 million F [15 million C] in the core), two things would happen. First, the gas would ionize, meaning that the electrons would be ripped away from the atoms. Second, the gas would expand. A lot. So much so that it would essentially explode.

But the Sun isn't just a random blob of gas. It's a really heavy random blob of gas (as are all stars). The



The Sun, seen here in ultraviolet light, is a massive, hot ball of gas. Because of its intense gravity, it can hold on to most of its mass. COURTESY OF NASA/SDO AND THE AIA, EVE, AND HMI SCIENCE TEAMS

gravity at the Sun's surface is about 28 times stronger than Earth's. That makes it really, really hard for the Sun to lose material. In fact, it's the tug-of-war between gravity, which wants to pull material inward, and radiation, which wants to push material outward, that allows the Sun to maintain equilibrium and keep producing energy for billions of years.

The Sun is mostly hydrogen, which makes up around 70 percent of its mass. Then comes helium, totaling 28 percent of the Sun's composition. The remaining 2 percent is everything else: about 1 percent oxygen, 0.3 percent carbon, and a smattering of even heavier elements.

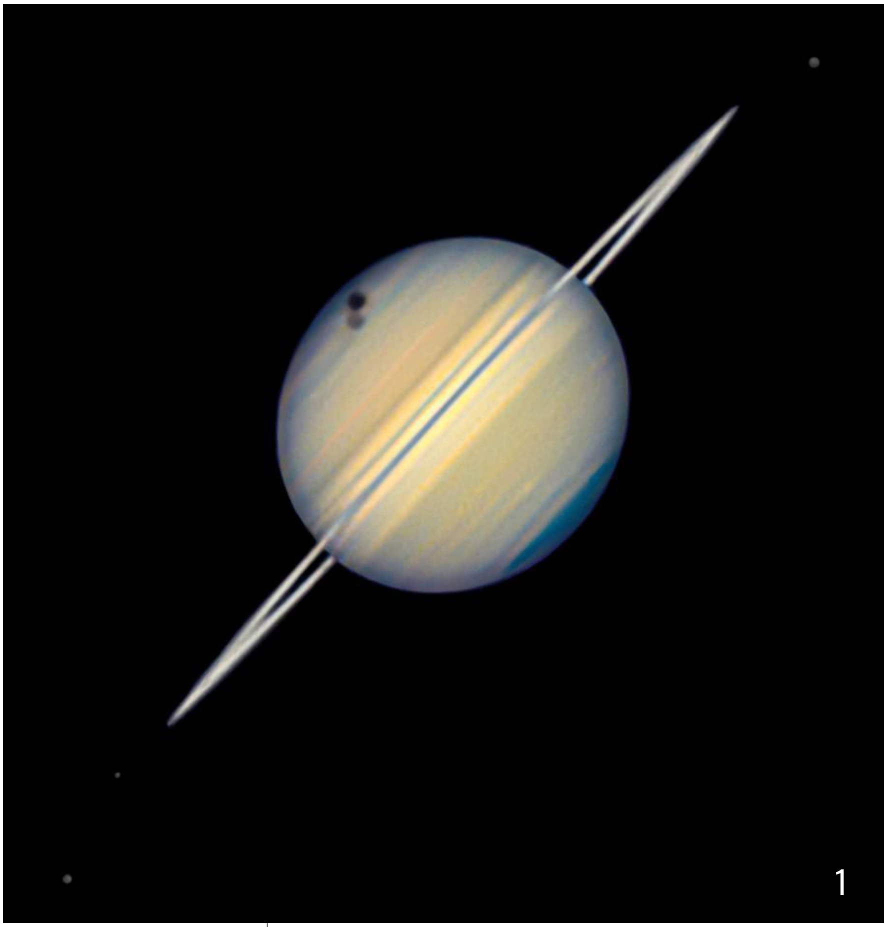
The Sun does lose material in the form of solar wind. Twisted-up magnetic fields can give subatomic particles enough energy to escape the Sun's enormous gravity. The solar wind carries away about 1 million to 2 million tons of mass every second, which adds up to the mass of Earth every 150 million years. But the Sun weighs more than 333,000 times Earth, so it's got plenty of mass to spare.

Paul Sutter

Cosmologist, Johns Hopkins University, Baltimore, Maryland

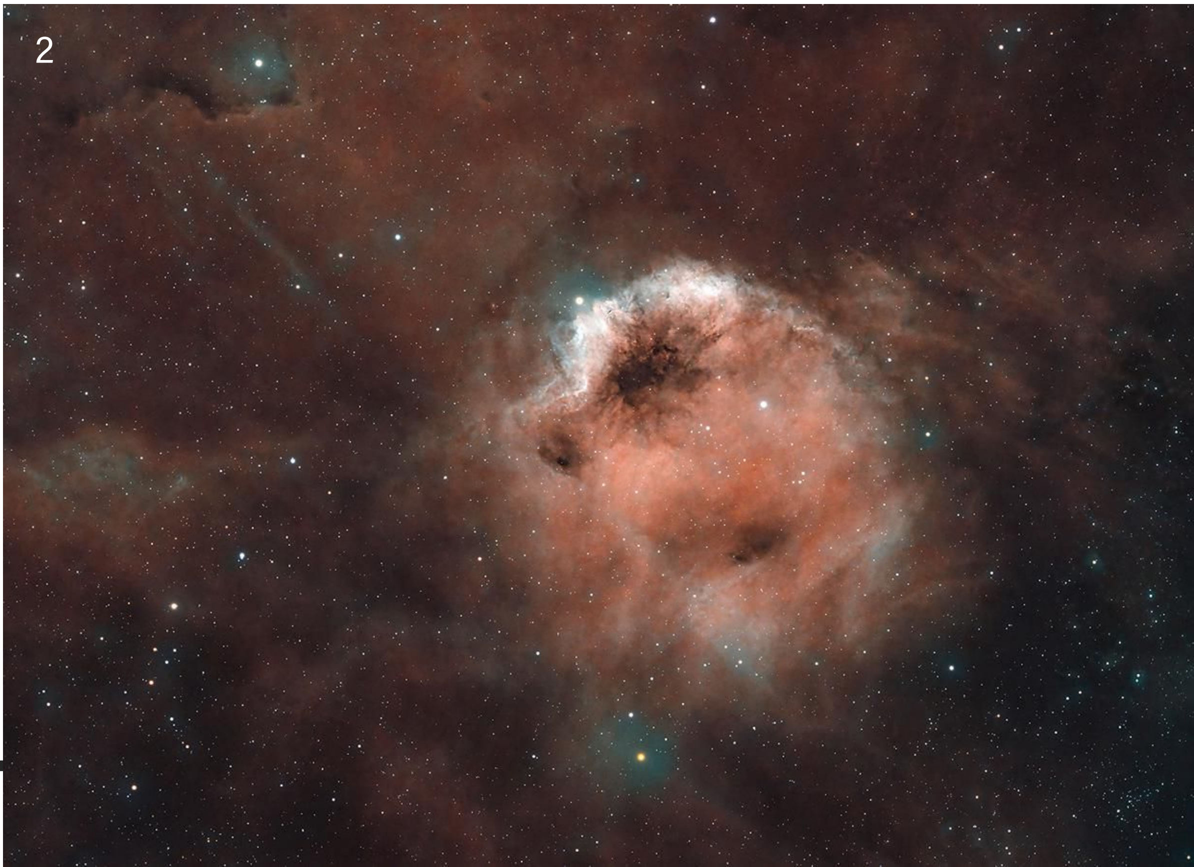
SEND US YOUR QUESTIONS

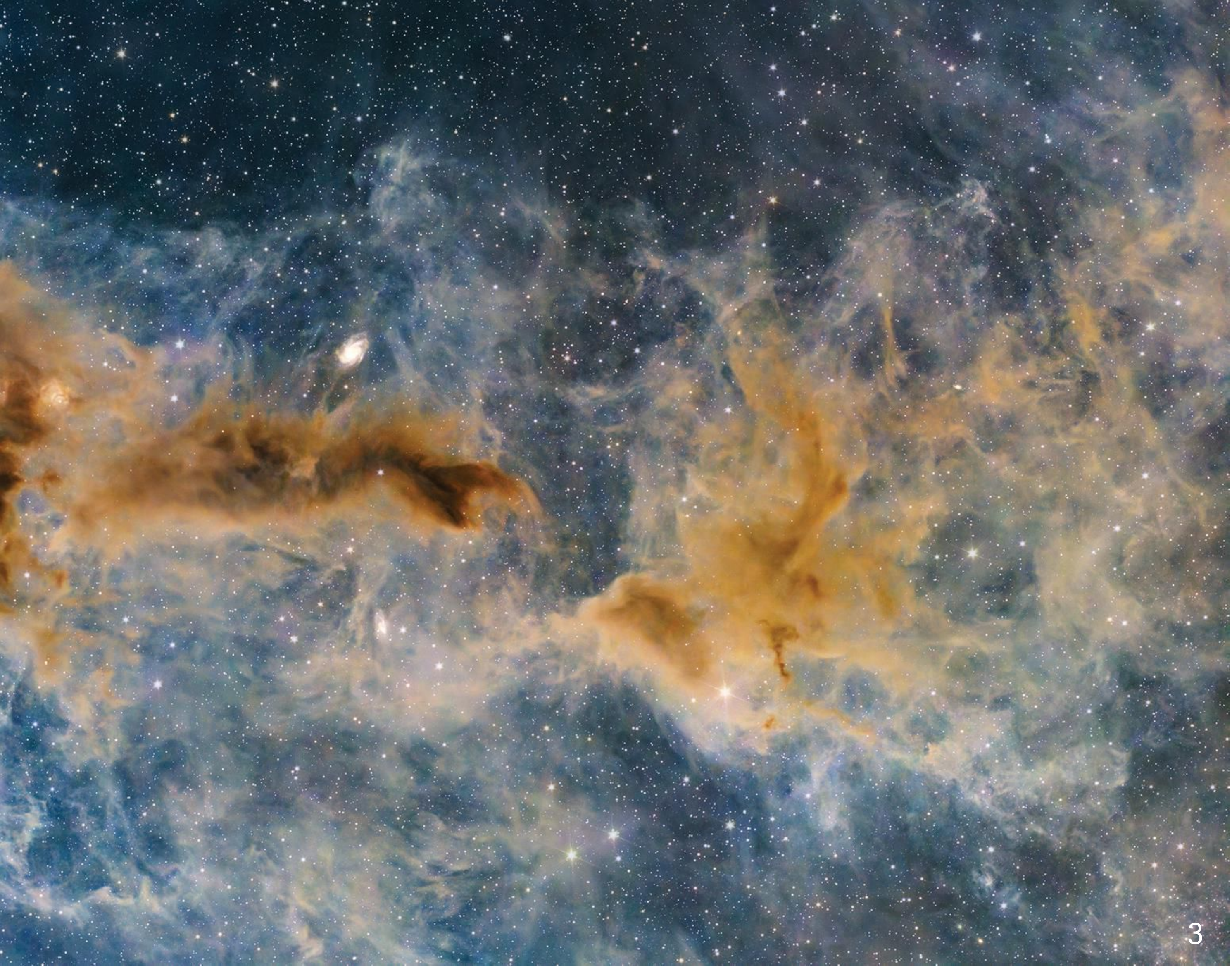
Send your astronomy questions via email to **askastro @astronomy.com**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

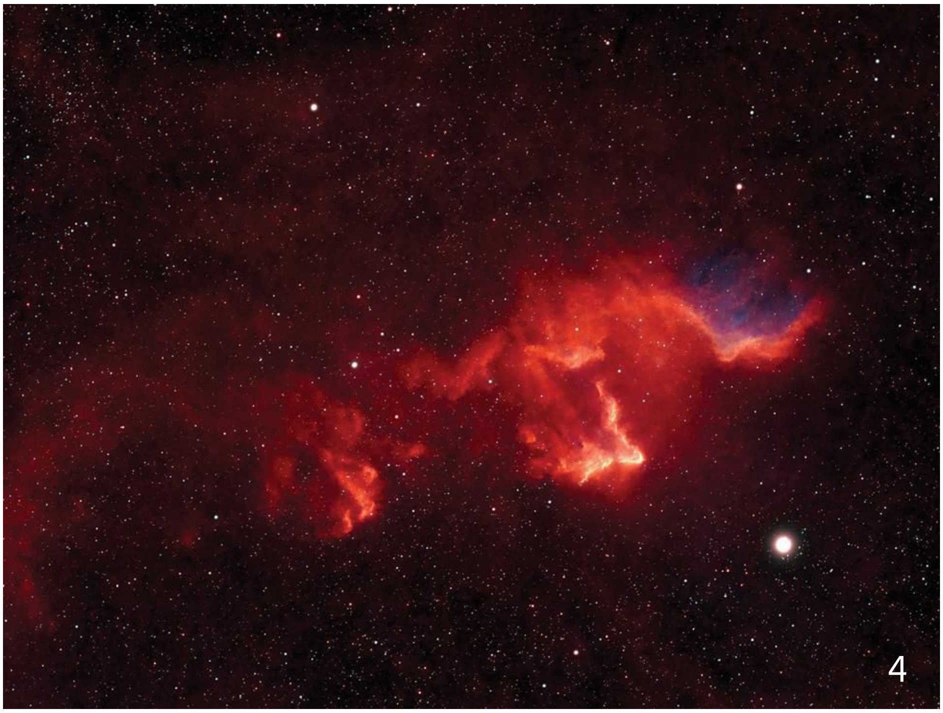


1. TITAN'S SHADOW TRANSIT
Due to Saturn's large axial tilt, its moons transit the planet only around ring plane crossings, which occur twice during the planet's 29.5-year orbit. The evening of Sept. 20/21 was the last transit of Titan's entire shadow until 2038. This photographer captured the event with a 9-inch scope and planetary camera, taking 75 minutes of video and stacking the top 25 percent clearest frames.
• *A.J. Smadi*

2. CUE THE ORGAN
The Phantom of the Opera Nebula (Sharpless 2–173) is an emission nebula around 10,000 light-years distant in Cassiopeia. The image comprises 8.2 hours of exposure with a 5-inch scope in the Hubble palette.
• *Pete Fleurant*



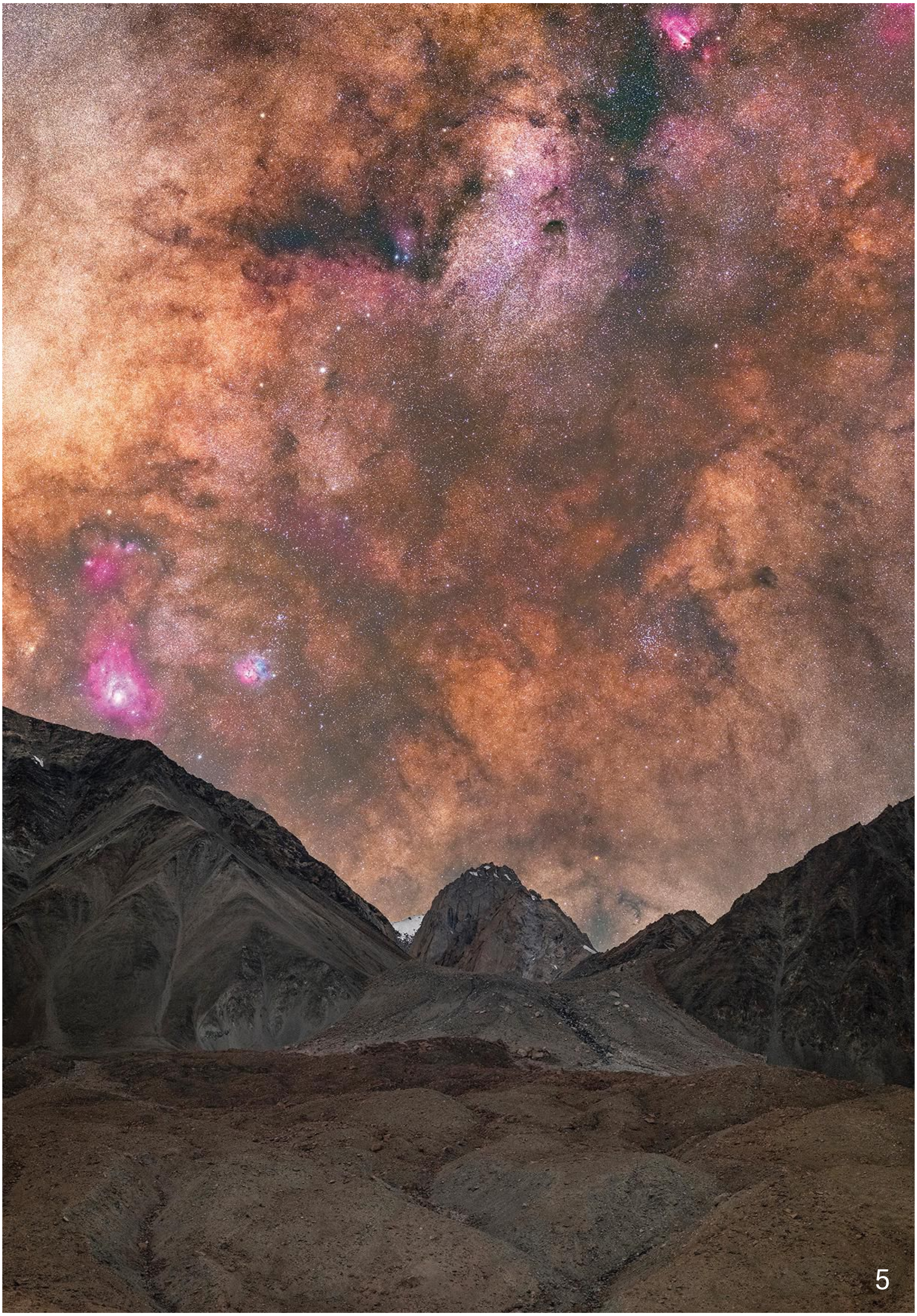




3. SPAWNING STARS
The dark nebula LDN 1251 in Cepheus — sometimes called the Rotten Fish Nebula — is a cold and dense cloud dotted by the occasional warm glow of forming stars within. The imager captured this region with a 14-inch scope at f/2 and four hours of RGB exposure. **▪ *Oleg Bouevitch***

4. IN HIDING
The reflection nebula IC 63 lies near the star Navi (Gamma [γ] Cassiopeiae). Through a telescope, the object often appears to be concealed by the star's glare, inspiring its common nickname, the Ghost of Cassiopeia. This imager took five hours of exposure with a 3-inch scope.
▪ *Andrei Pleskatsevich*

5. GALACTIC HIGH
The Milky Way soars above mountain peaks in this nightscape taken from the village Merak at an elevation of 14,000 feet (4,300 meters) in Ladakh, India. Visible deep-sky objects include M8 and M20 (left). The imager used a Nikon mirrorless camera and 135mm lens to take 24 one-minute exposures at f/2.8 and ISO 3200; the foreground is 5 three-minute exposures at ISO 2000.
▪ Soumyadeep Mukherjee



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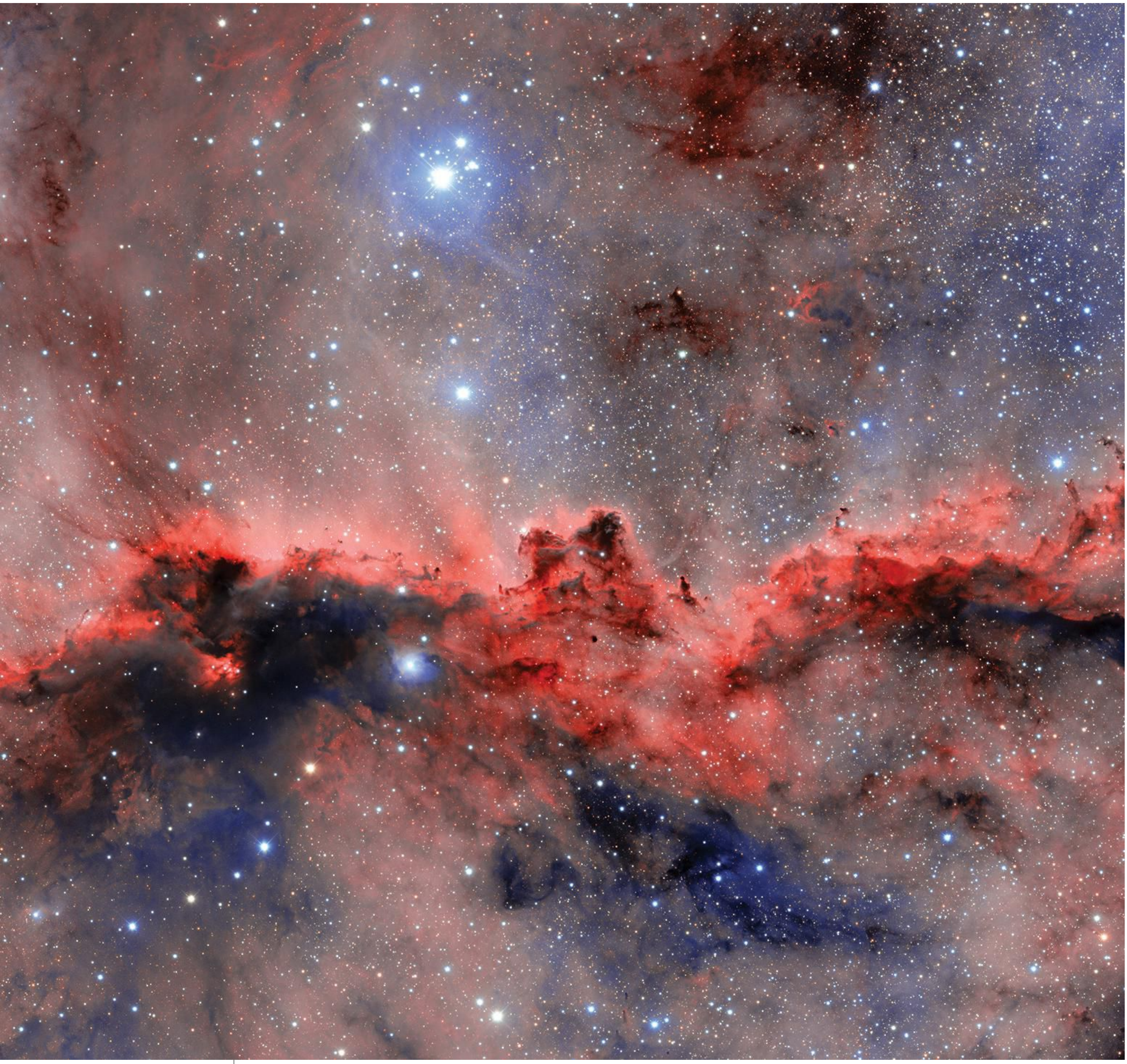

A FIGHT TO THE DEATH

The Milky Way's plane cuts through the northwestern corner of Ara the Altar, blessing this southern constellation with a surplus of deep-sky delights. But perhaps none surpasses the stunning emission nebula known as the Fighting Dragons of Ara, the Rim Nebula, or simply NGC 6188. The battling mythological beasts face off at the center of this image, their dark bodies enveloped in the reddish glow of ionized hydrogen. The brightest stars in open cluster NGC 6193 (seen above and slightly left of the dragons) rank among the hottest stars known. Their radiation ionizes the hydrogen along the rim of a massive molecular cloud while their powerful stellar winds sculpt the nebula's intricate silhouettes. NGC 6188 lies about 4,000 light-years from Earth. DARK ENERGY SURVEY/DOE/FNAL/DECAM/CTIO/NOIRLAB/NSF/AURA

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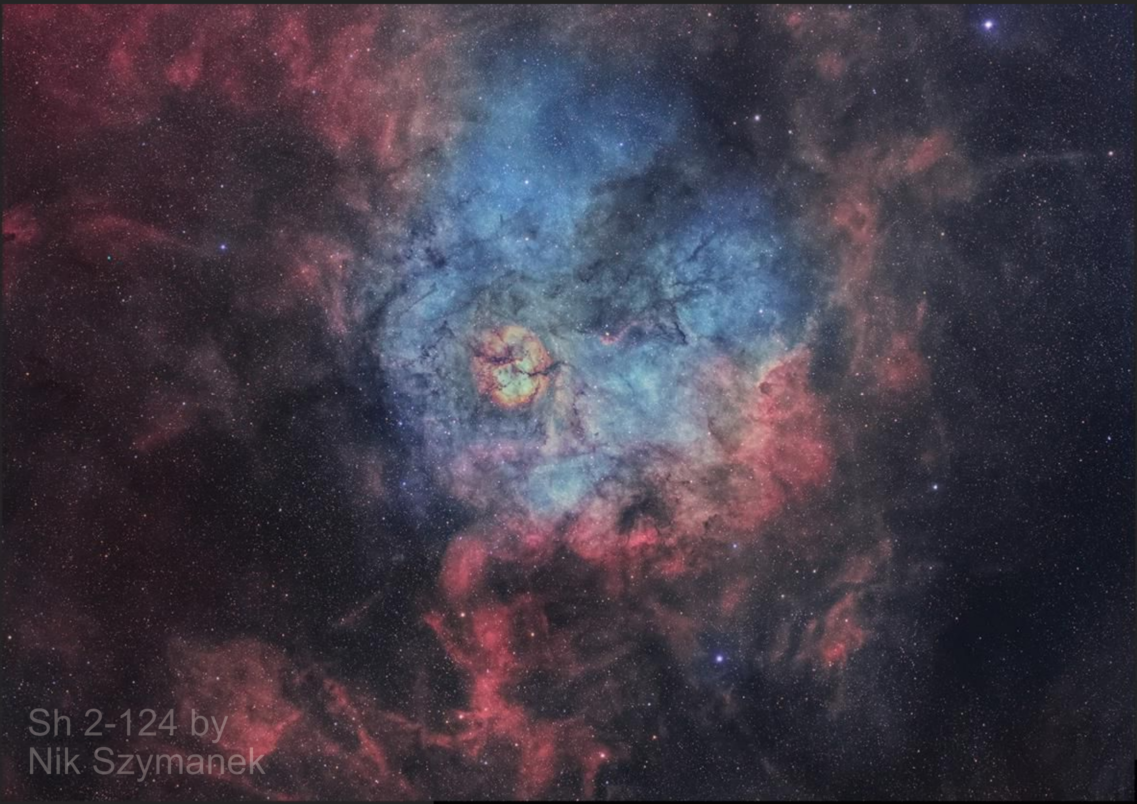

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SOUTHERN SKY

BY MARTIN GEORGE

March 2026

The Moon’s earthly shadow

Early March finds us in a dramatic lull as far as viewing naked-eye planets goes, with four of them being uncomfortably close to the Sun for observation. Fortunately, that fate doesn’t apply to **Jupiter**. The giant planet remains prominent in the northern sky all evening, shining at magnitude –2.4 among the stars of central Gemini. Jupiter’s motion relative to the Twins’ backdrop is nearly imperceptible this month, as the planet reaches its stationary point March 11.

At a declination of 23°, Jupiter lies about as far north as it can get, which places it relatively low in the sky for Southern Hemisphere observers. It’s still worth taking a look through your telescope, however, particularly when the planet stands highest in the north in early evening. Jupiter’s 41"-diameter disk should show a wealth of atmospheric detail during moments of good seeing. And it’s always fun tracking the movements of the four bright Galilean satellites from night to night.

Before looking at Jupiter, see whether you can catch a final evening glimpse of **Saturn**. Although the ringed world is heading toward solar conjunction March 25, you might still spot the magnitude 1.0 object low in the west after civil twilight ends early in the month. Your odds improve if you live closer to the equator. But don’t bother pointing your telescope at Saturn. Your next decent view won’t come until it climbs higher in the morning sky later this autumn.

Mercury reaches inferior conjunction March 7, but then sweeps rapidly into view before dawn. Although the innermost planet won’t reach greatest elongation until early April, the views during the final week of March should be spectacular.

On the 24th, Mercury glows at magnitude 0.8 and stands 10° high in the east an hour before sunrise. A telescope shows the planet’s 9"-diameter disk, which appears 30 percent lit. By the 31st, Mercury shines at magnitude 0.4 and has gained 4° of altitude. Its disk then measures 8" across and is 44 percent illuminated.

Look for **Mars** some 10° below Mercury at the end of the month. The Red Planet shines at magnitude 1.2 and will be harder to see than its companion. Don’t bother with your telescope — Mars’ 4"-diameter disk will show no detail.

The end of March is also the time to look for **Venus**. The inner world enters the evening sky late this month but stands only 5° high in the west 30 minutes after sunset. Shining brilliantly at magnitude –3.9, it should just be visible if you have an unobstructed horizon. As with Mars, a telescope adds nothing to the view.

A total lunar eclipse takes place March 3. The best viewing locations in the Southern Hemisphere are the Pacific Ocean, New Zealand, and Australia. The umbral phase of the eclipse begins at 9h50m UT and ends at 13h18m UT, with totality running from 11h04m to 12h03m UT.

The starry sky

A few months ago, I was gazing at the constellation Canis Major when it was visible in the small hours of the morning toward the east. I always enjoy looking at the stars southeast of brilliant Sirius, whose shape reminds me of a coat hanger without a hook. My thoughts wandered to considering the name of that constellation, and how so many people pronounce its first three letters as if it rhymes with “man” or “tan.”

Over the years, however, I have delved into the “correct” ways to pronounce constellation names — as well as those of stars and some clusters, too. When I was little, I thought that the Beehive Cluster (M44), or Praesepe, in Cancer should be pronounced “pray-seep,” though I soon found out I was wrong. The correct way seems to be “pree-see-pee.” Even so, in H.B. Rumrill’s 1936 paper published by the Astronomical Society of the Pacific, he suggests a pronunciation of “pree-seep.”

Let’s head back to the Great Dog, which conveniently passes nearly overhead on March evenings. You will find the authoritative pronunciation for the constellation’s first word is “caynis,” which few people use — certainly not those in Australia, anyway.

Many guides to pronouncing astronomical names exist, but a favorite of mine is one published in some editions of the classic *Norton’s Star Atlas*. Browsing through that list, you’ll find many pronunciations matching what you would expect, such as Sirius. Others, not so much. Take Caelum the Chisel. It’s proper to say “see-lum,” with the “cae” being pronounced the same way as the “ce” in Cetus the Whale.

I find it instructive to look through some of these lists to confirm correct pronunciations. Nearly all agree that the constellation of the River should be “e-RID-a-nus.” But it’s not hard to uncover inconsistencies among sources. *Norton’s* suggests, for example, that the first two letters of Monoceros the Unicorn should be pronounced like “moh,” rhyming with “toe,” while other sources suggest “mon” for the first three letters. However, they all agree that the emphasis should go on the “nos.”

How about the southern constellation Grus the Crane? Although rhyming it with “truss” sounds wrong — I have always said it as “groose” — the former is listed by *Norton’s* (though one listing suggests both are acceptable).

Many names are so ancient that we may never know how people pronounced them originally, but it’s still fun doing the research.

STAR DOME

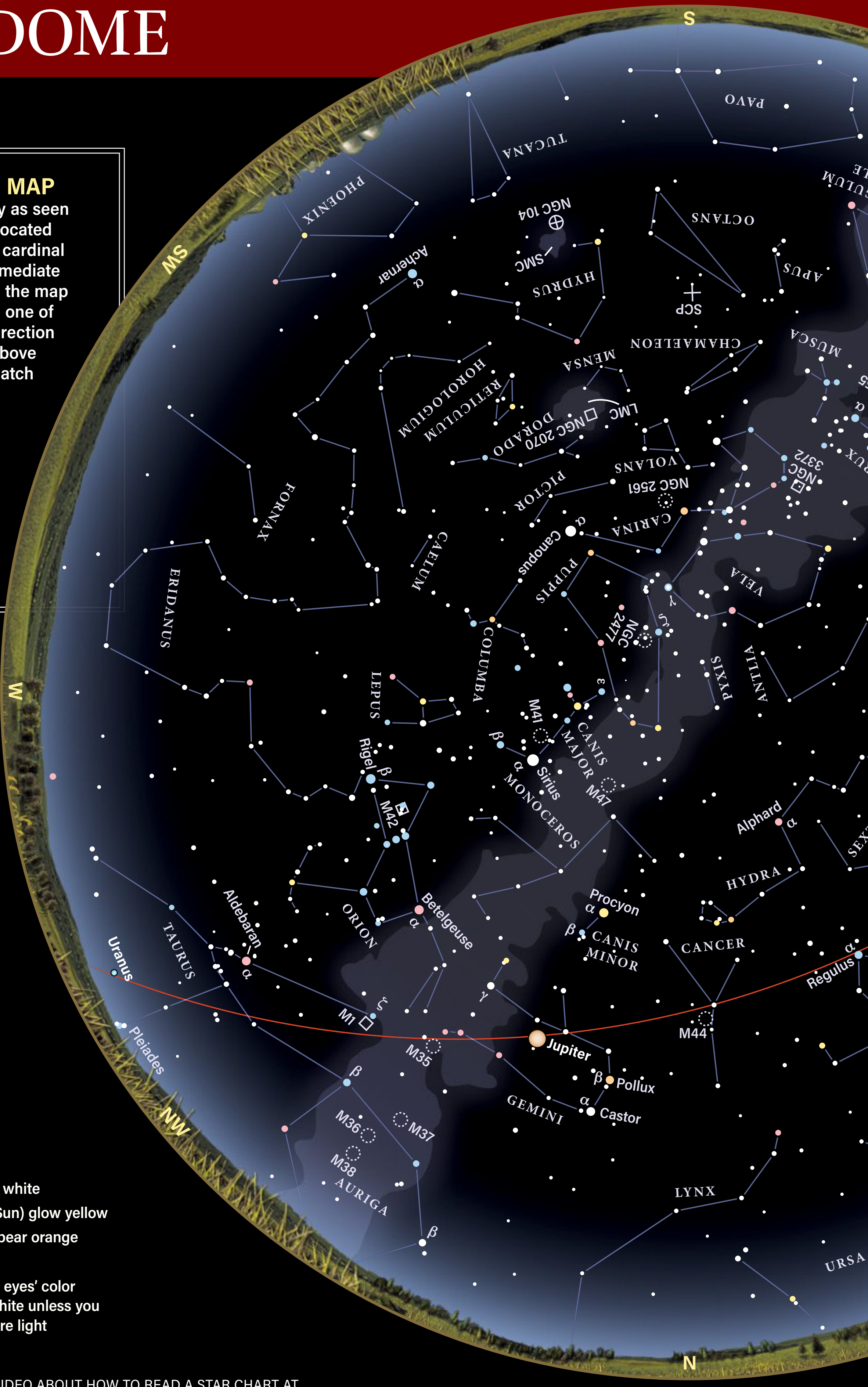
HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. March 1
9 P.M. March 15
8 P.M. March 31

Planets are shown at midmonth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M41
CANIS MAJOR
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M47
Rigel
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M42
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CANIS MINOR
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Regulus
Aldebaran
ORION
Betelgeuse
Uranus
TAURUS
M1
M35
Jupiter
M44
Pleiades
Pollux
GEMINI
Castor
M36
M37
M38
AURIGA
LYNX
URSA

MAP SYMBOLS

- ◌ Open cluster
- ⊕ Globular cluster
- ☐ Diffuse nebula
- ⌖ Planetary nebula
- ⬭ Galaxy

STAR MAGNITUDES

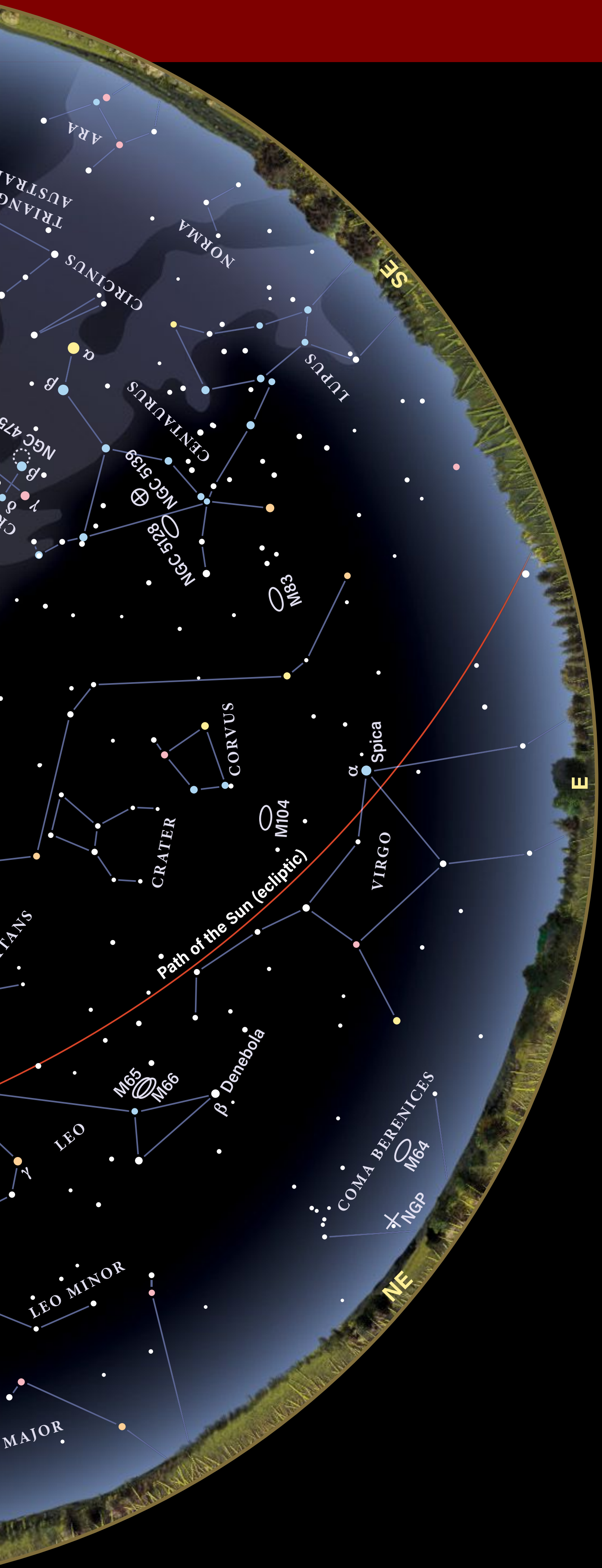
● Sirius	
● 0.0	• 3.0
● 1.0	• 4.0
• 2.0	· 5.0

STAR COLORS

A star's color depends on its surface temperature.

- 🟦 The hottest stars shine blue
- ⬜ Slightly cooler stars appear white
- 🟨 Intermediate stars (like the Sun) glow yellow
- 🟧 Lower-temperature stars appear orange
- 🟥 The coolest stars glow red
- ⬜ Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**


ARA
TRIANGULUM AUSTRA
NORMA
CIRCINUS
SE
LUPUS
α
β
CENTAURUS
NGC 5139
NGC 5128
NGC 47
M83
CORVUS
α
Spica
E
M104
CRATER
VIRGO
Path of the Sun (ecliptic)
TANS
M65
M66
β
Denebola
LEO
γ
COMA BERENICES
M64
NGP
NE
LEO MINOR
MAJOR

MARCH 2026

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

2 The Moon passes 0.4° north of Regulus, 13h UT

Asteroid Pallas is in conjunction with the Sun, 15h UT

3 Full Moon occurs at 11h38m UT; total lunar eclipse

7 Mercury is in inferior conjunction, 11h UT

10 The Moon passes 0.7° south of Antares, 12h UT

The Moon is at apogee (404,384 kilometers from Earth), 13h43m UT

11 Jupiter is stationary, 3h UT

Last Quarter Moon occurs at 9h39m UT

15 The Moon passes 1.0° north of Pluto, 1h UT

17 The Moon passes 2° south of Mercury, 14h UT

The Moon passes 1.5° north of Mars, 22h UT

19 New Moon occurs at 1h23m UT

Mercury is stationary, 20h UT

20 The Moon passes 5° north of Venus, 13h UT

March equinox occurs at 14h46m UT

21 Asteroid Massalia is at opposition, 15h UT

22 Neptune is in conjunction with the Sun, 11h UT

The Moon is at perigee (366,857 kilometers from Earth), 11h40m UT

23 The Moon passes 5° north of Uranus, 8h UT

25 Saturn is in conjunction with the Sun, 9h UT

First Quarter Moon occurs at 19h18m UT

26 Mars is at perihelion (207 million kilometers from the Sun), 7h UT

The Moon passes 4° north of Jupiter, 12h UT

29 The Moon passes 0.3° north of Regulus, 20h UT

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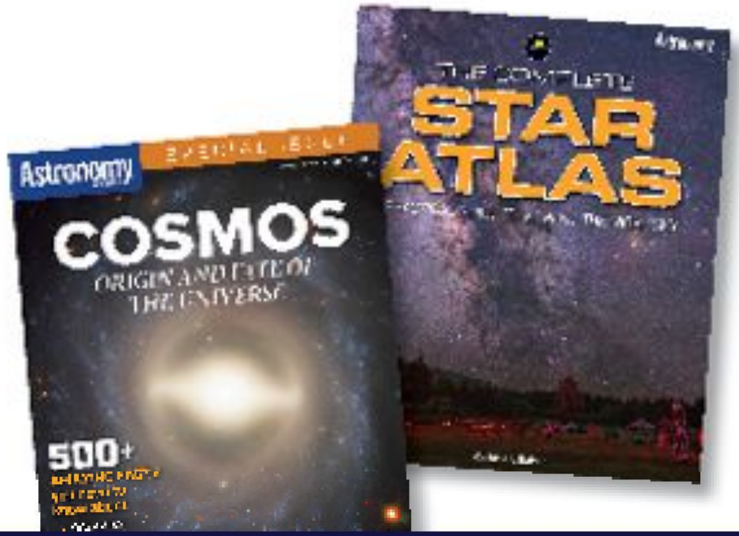
GALILEOSCOPE

The Milky Way from above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